Final Report

Corrective Measures Study Cooling Water Canal (SWMU No. 5) Peñuelas Technology Park LLC Peñuelas, Puerto Rico

Prepared for

Peñuelas Technology Park LLC

A Wholly Owned Subsidiary of The Dow Chemical Company

EPA Facility I.D. No. PRD980594618

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CH2MHILL®

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Acronyms and Abbreviations

°C	degrees Celsius
ADCP	Acoustic Doppler Current Profiler
BERA	Baseline Ecological Risk Assessment
BMP	best management practice
bss	below sediment surface
cm/d	centimeters per day
CMS	Corrective Measures Study
COPC	constituent of potential concern
CORCO	Commonwealth Oil Refining Company
CPT	cone penetrometer test
CSA	CSA International, Inc.
CSM	conceptual site model
CWC	Cooling Water Canal
DENR	Puerto Rico Department of Environment and Natural Resources
ESV	ecological screening value
ft^2	square feet
GCL	geocomposite clay liner
gpm	gallons per minute
GPS	global positioning system
HDPE	high-density polyethylene
ILFA	Industrial Landfill Area
kn	knots
LLDPE	linear low-density polyethylene
LOI	loss on ignition
µg/L	micrograms per liter
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
mm/s	millimeters per second
MSGP	Multi-Sector General Permit
msl	mean sea level
NADAS	Navigation and Data Acquisition System
NAPL	non-aqueous phase liquid
NCWRL	North Cooling Water Return Lateral

NOAA	National Oceanic Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
O&M	operations and maintenance
PAH	polycyclic aromatic hydrocarbon
POC	Peerless Oils & Chemicals, Inc.
PPE	personal protective equipment
psf	pounds per square foot
PTPLLC	Peñuelas Technology Park LLC
QC	quality control
RCM	Reactive Core Mat
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
SCWRL	South Cooling Water Return Lateral
SWMU	Solid Waste Management Unit
SVOC	semivolatile organic compound
T	transect
TMV	toxicity, mobility, or volume
TOC	total organic carbon
TS	Treatability Study
TSS	total suspended solids
TSWP	treatability study work plan
UCCLLC	Union Carbide Caribe, LLC
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
VOC	volatile organic carbon
WWTP	wastewater treatment plant
yd^3	cubic yards

SECTION 1

Introduction

1.1 Purpose

This document represents the Resource Conservation and Recovery Act (RCRA) Corrective Measures Study (CMS) Report for the Cooling Water Canal (CWC) at the Peñuelas Technology Park LLC (PTPLLC) facility, formerly the Union Carbide Caribe, LLC (UCCLLC) site, in Peñuelas, Puerto Rico. Figure 1-1 presents a facility location map. The purpose of this CMS is to identify and evaluate potential remedial alternatives for the releases of hazardous constituents that have been identified in the CWC sediments.

Solid Waste Management Unit (SWMU) No. 5 is the closed North Cooling Water Return Lateral (NCWRL) Canal (stabilized and filled) and the sediments within the remaining, unfilled, portion of the CWC in the current facility RCRA Part B Permit (U.S. Environmental Protection Agency [USEPA] 2003).

This CMS report addresses the impacted sediments in the CWC and summarizes the results of the investigations and studies to characterize the impacted sediments. This report presents the corrective measure objectives, development and evaluation of specific corrective measure alternatives, and a summary of the recommended remedy.

1.2 Facility Background

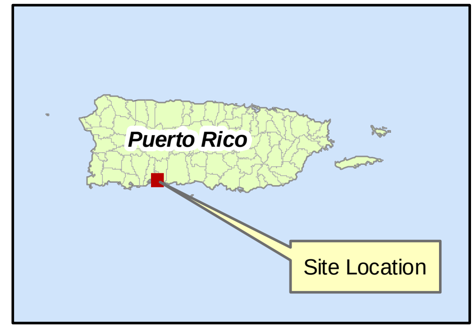
1.2.1 Description

The PTPLLC facility, which was formerly a petrochemical manufacturing facility, occupies approximately 633 acres of low-lying land along the southern coast of Puerto Rico. As shown in Figure 1-1, the facility is bounded to the north and west by the Commonwealth Oil Refining Corporation (CORCO) bulk fuel terminal, to the south by Tallaboa Bay of the Caribbean Sea, and to the east by the Tallaboa River.

The PTPLLC facility is comprised of two main areas: the Main Plant Area and the Puntilla Area. The Main Plant Area is where the former petrochemical manufacturing facility was located, which has since been demolished and dismantled. This area is relatively flat and is now mostly covered with grasses and scrub vegetation, with some remnant concrete support pads and foundations. The eastern portion of the site along the Tallaboa River consists of undeveloped forest. The CWC is located along the west side of the Main Plant Area.

Two parcels of the Main Plant Area have been sold. One parcel is now owned by Peerless Oil & Chemicals, Inc. (POC) along the Tallaboa Bay shoreline, and the other is owned by Tallaboa Tank & Fabrications in the northeastern portion of the facility. The POC property is used as a bulk petroleum fuel terminal, and the Tallaboa Tank & Fabrications property is used mainly for the fabrication of steel tanks.

The Puntilla Area consists of a peninsula extending from the Main Plant Area to the southwest, and separates Tallaboa Bay and Guayanilla Bay. A small out-of-service tank farm exists at the end of the Puntilla Area, and the facility wastewater treatment plant (WWTP) is located midway down the Puntilla Area along the Tallaboa Bay shoreline. Three parcels of property in the Puntilla Area have been sold. One parcel located along Tallaboa Bay at the northern end of the Puntilla is owned by POC; the other two parcels are located at the southern end of the Puntilla and are owned by POC and Ecoelectrica. The POC parcels are used as a bulk fuel terminal and for tanker truck loading of fuel products, and Ecoelectrica operates a natural gas-fired power plant. A small parcel of land at the very end of the Puntilla Area is owned by the Ponce Port Authority, and it includes a small pier for loading/unloading of fuel products.



Legend

- UCCLLC Property Boundary
- Facility Boundary

Sources:
1. Sample Points: CH2M HILL, 2008
2. Aerials: USDA, 2007

North

0 500 1,000 2,000
Feet

FIGURE 1-1
Facility Location Map
SWMU No. 5, CMS Report
PTPLLC, Peñuelas, Puerto Rico

1.2.2 History

UCCLLC operated a petrochemical manufacturing plant on the site from 1959 through 1985; the plant has since been decommissioned. Over the past 20 years nearly all of the buildings, plant process equipment, and utility infrastructure systems on the plant site have been removed, demolished, or abandoned in place.

While in operation, the plant produced olefins (ethylene and propylene), butadiene, polyethylene, aromatics (benzene, toluene, xylene, cumene), ethylene glycol ethers, butanol, acetone, phenol, and a phenolic derivative (bisphenol-A). Dripolene, commercially known as pyrolysis fuel, was produced as a byproduct residue of the furnace cracking reactions used to produce ethylene. The dripolene was removed from the production stream and disposed of in the Industrial Landfill Area (ILFA), which included the former Industrial Landfill (SWMU No. 20) and the former Dripolene Pond (SWMU No. 15), located north of the CWC (SWMU No. 5). The Dripolene Pond, stormwater control pond, and Industrial Landfill have been closed and capped under the facility RCRA permit. A groundwater extraction system has been in operation since 1991 to control the potential migration of constituents from the ILFA to the CWC.

1.3 Cooling Water Canal Background

1.3.1 Description

The CWC is a constructed open channel, much of which is navigable, running along the west side of the former manufacturing area of the PTPLLC site, and exiting to Tallaboa Bay to the south. Figure 1-2 shows the SWMU No. 5 project location and layout. The CWC banks are nearly vertical, approximately 2 to 5 feet high, and vegetated with mangroves along most of their length, except in the southern portion in which the bank is seawall, boulders, or other constructed surfaces. The CWC is approximately 3,000 feet long and ranges in width from approximately 50 feet at the northern end to more than 300 feet at the southern end. Water depth normally ranges from less than 3 feet at the northern end to approximately 16 feet at the southern end. Seasonal precipitation and tidal fluctuations control the direction and rate of flow in the CWC. A paved vehicle bridge crosses the canal approximately 400 feet south of the northern end, and a pipe rack bridge crosses the canal approximately 800 feet north of the southern end. The site topography in the vicinity is flat with little relief, with land surface elevations typically less than 10 feet above mean sea level (msl). Land side access to the CWC is via a paved road and a boat dock along the eastern bank, and a vehicle bridge near the northern end.

1.3.2 Operational History

There are three canals that have historically operated onsite: the CWC, the NCWRL Canal, and the South Cooling Water Return Lateral (SCWRL) Canal. The closed NCWRL and SCWRL Canals were constructed in 1959 primarily to return approximately 50,000 gallons per minute (gpm) of noncontact cooling water to Tallaboa Bay. The site's RCRA permit lists the CWC as part of the Group III SWMUs because it transported wastewater, including sanitary waste, waste lime, carbon water, glycol, and pyrolysis oil (dripolene), prior to the existence of the WWTP and because it received seepage from the ILFA, located near the north end of the CWC. Historical releases and seepage from the ILFA are believed to be the source of polynuclear aromatic hydrocarbons (PAHs) in CWC sediments.

The existing CWC runs north to south, and historically it was connected at the northern end with the NCWRL Canal, which ran in an east-west direction immediately south of the ILFA. The NCWRL Canal and the northern 100 feet of the main CWC were backfilled in 1988 because dripolene constituents were present along the banks of the CWC and in sediments from the ILFA.

The NCWRL Canal was closed in the late 1980s. NCWRL sediments, impacted with dripolene, were either stabilized in situ or stabilized and removed to the ILFA (SWMU No. 20). The NCWRL Canal was then backfilled and compacted with clean fill to prevent further migration of impacted groundwater emananting from this area (USEPA, 2003).

FIGURE 1-2
Project Location
SWMU No. 5, CMS Report
PTPLLC, Peñuelas, Puerto Rico

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The SCWRL Canal (running east-west) is approximately 1,500 feet long, connecting to the eastern side of the CWC approximately 1,200 feet north of Tallaboa Bay (Figure 1-2).

Stormwater reaching the CWC from the following areas flows to Tallaboa Bay:

- A ditch surrounding the newly closed portions of the landfill collects stormwater from the closed ILFA and routes it to Stormwater Outfall S09, which discharges directly into the CWC at the north end (under the National Pollutant Discharge Elimination System [NPDES] Program's Multi-Sector General Permit [MSGP], the Stormwater Permit).
- A stormwater control ditch, parallel to Puerto Rico Road 337, is designed to prevent offsite stormwater from discharging at permitted Stormwater Outfall S09; this ditch collects stormwater and routes it into the canal south of regulated Stormwater Outfall S09.
- The SCWRL Canal receives no regulated discharges; however, the SCWRL Canal may receive sheet flow runoff from the surrounding area.

There are no other upstream sources of flow into the canal (CH2M HILL 2012a). Tidal circulation is the predominant source of flow and hydraulic stage within the canal.

1.3.3 Investigation and Response History

The CWC is hydraulically downgradient of the ILFA and has sustained impacts from former dripolene disposal operations. Investigations to assess the nature and extent of dripolene-related impacts to CWC sediments were conducted from 1977 through 2013.

Oil sheens historically have been visible on the water surface at the CWC dating back to the early 1970s. Phase I and Phase II RCRA Facility Investigations (RFIs), conducted by UCCLLC, confirmed the presence of several site-related chemicals in CWC sediment, reporting highest levels in the northern half of the canal and levels decreasing toward the canal mouth (Union Carbide Corporation 2000; Union Carbide Corporation 2001). Focused sampling of canal sediment and surface water in 2000 indicated that all analyzed surface water parameters were below detection limits.

Former mitigation actions related to dripolene entering the NCWRL Canal and the CWC consisted of the following:

- Installing a bentonite slurry wall between the Dripolene Pond and the NCWRL Canal (1970).
- Installing floating skimmer booms in the CWC (1974).
- Dredging, stabilizing, and disposing of some the dripolene-contaminated sediments from areas within the NCWRL Canal (1974) and the north end of the CWC (1977). These sediments were placed in the ILFA.
- Stabilizing sediments in situ in the NCWRL Canal and approximately 100 feet of the north end of the CWC using a mixture of caliche and fly ash (1988)
- Backfilling the NCWRL Canal and the northern 100 feet of the CWC with caliche (1988).
- Closing the Dripolene Pond by stabilizing the dripolene waste in place using a mixture of caliche and fly ash (1988).
- Installing a groundwater recovery well system (1991) for hydraulic containment along the south and west sides of the ILFA to control further discharge of dripolene and dripolene-impacted groundwater to the CWC.
- Closing the ILFA (including stormwater pond) for long-term containment of landfill wastes including stabilized and solidified dripolene sludge (2011).

Investigative and study activities include the following:

- Performing RCRA Facility Investigation (RFI), as documented in the *Detection RFI Report* (UCC, March 28, 1991, August 25, 1993 Addendum), which included the collection and analysis of 3 sediment samples from the canal. The sample locations were near the northern end of the canal, near the boat house, and about 2/3 down the canal from its northern end (about 1,000 feet north of the mouth of the canal). Elevated levels of styrene, toluene, and benzo(a) anthracene were detected, and additional RFI activities were recommended.
- Performing Phase I RFI, as documented in the *Phase I RCRA Facility Investigation Report for Group SWMUs, Volume 1* (UCC, January 28, 2000). Several sediment samples were collected for analysis and the results indicated elevated levels of PAHs, primarily benzo(a)anthracene, with decreasing concentrations toward the southern end (mouth) of the canal. A Phase II RFI and Corrective Measures Study were recommended.
- Performing a management-level ecological risk assessment (2000) to evaluate initial environmental data for potential risk to aquatic organisms. This report is discussed in more detail in the following section (Section 1.3.4)
- A Corrective Measures Study (UCC, 2001) was conducted to develop corrective measures to reduce ecological exposure to the impacted sediments to acceptable levels (URS Corporation 2001). Potential remedial alternatives included leaving contaminated sediments in place and installing a subaqueous multimedia cap and/or filling portions of the canal.
- Performing a baseline ecological risk assessment (2005) to evaluate additional sediment and tissue (fish, invertebrates, plants) data for potential risk to aquatic organisms and wildlife. This report is discussed in more detail in the following section (Section 1.3.4)
- A CMS work plan for SWMU No. 5 (CH2M HILL 2008) was prepared to set the objectives of the CMS. This report is discussed in more detail in Section 1.3.6.
- A treatability study work plan was prepared (CH2M HILL 2011) to design the laboratory and field pilot activities. This plan is discussed in more detail in Section 1.3.7.
- Performing a focused RFI to investigate physical, chemical, and geotechnical properties of sediment to support a CMS. The final RFI report was prepared in 2012. This report is discussed in more detail in Section 1.3.5.
- Conducting treatability studies (laboratory and field scale) to support canal sediment closure alternatives. There were two phases: Phase 1 consisted of sediment sampling and testing for physical and chemical properties, and Phase 2 consisted of pilot scale testing of capping, backfilling, and support activities. These reports are discussed in more detail in Section 1.3.7, and complete reports of these studies are appended to this CMS.
- Performing benthic macroinvertebrate community sampling and risk analyses in 2013 to more directly assess the potential impact of sediment constituents to benthic organisms. These studies supported a less intrusive remedial approach consisting mainly of containment of the canal sediments above the vehicle bridge. Results of the studies were presented in 2014 and are discussed further in Section 1.3.8. Updates to the RFI and BERA were made in 2014 to record the benthic study results.

As noted above, a groundwater recovery system was installed in the Industrial Landfill Waste Management Area (ILFA) in 1991 for hydraulic containment along the south and west sides of the ILFA to control further discharge of dripolene and dripolene-impacted groundwater to the CWC. The current RCRA permit, which became effective in November 2003, requires continued operation of this groundwater recovery system at the ILFA until the groundwater compliance monitoring results for the groundwater compliance wells demonstrate that the concentrations of the constituents of concern (COCs) are less than the Groundwater Protection Standards (GPS) contained in the permit. The GPS were established for the protection of ecological receptors in the Cooling Water Canal and Tallaboa Bay based on the presumed lateral COC migration pathway of groundwater-to-surface water. Therefore, PTPLLC will not be able to terminate the groundwater recovery system until the COC concentrations in the groundwater no longer present a risk to receptors in the Cooling Water Canal. As such, it is unlikely that residual COC concentrations in the groundwater following termination of the groundwater recovery system would migrate to and impact sediments in the lower canal.

In addition, the draft RCRA Post Closure Care Permit renewal application which was submitted to the USEPA in May 2013 included the same groundwater recovery operations included in the current RCRA permit as well as the same GPS. Based on review comments received to date on the draft RCRA renewal permit application, the USEPA has not requested a change in the groundwater recovery operations or the GPS, as required in the current RCRA permit or as proposed in the draft RCRA permit renewal application.

1.3.4 Ecological Risk Evaluations

Management-Level Ecological Risk Assessment

A Management-Level Ecological Risk Assessment (URS Corporation 2000) was conducted for the CWC in 2000. No constituents of potential concern (COPCs) were detected in canal surface water that would potentially pose a risk to aquatic receptors. Volatile organic compounds (VOCs) and semivolatile organic compounds (SVOCs) in sediment were identified as COPCs, however, and were detected at concentrations that could potentially impact marine benthic macroinvertebrate communities in the CWC.

Baseline Ecological Risk Assessment

CH2M HILL conducted a Baseline Ecological Risk Assessment (BERA) in 2005 to evaluate potential risk of sediment constituents to ecological receptors at the site, according to prescribed regulatory criteria (CH2M HILL 2006). The final *Baseline Ecological Risk Assessment, SWMU No. 5, Cooling Water Canal ()*, dated June 2006 (USEPA ID No. PRD980594618), received final USEPA approval on August 21, 2006. As part of the BERA, CH2M HILL collected a series of surface sediment (0 to 18 inches) and associated aquatic biota samples (that is, fish, crabs, and sea grass) for the analysis of VOCs and SVOCs and the evaluation of potential risk to benthic organisms and wildlife through direct exposure or via the food chain.

Figure 1-3 shows the sampling locations from the 2005 BERA investigation. VOCs were not detected in surface sediment, and were detected in only one of six subsurface samples. The highest SVOC levels were observed in the 12- to 18-inch depth interval in sample ST2, in the north-central portion of the canal, with significant concentration decreases southward in the CWC.

The BERA concluded that direct contact with sediments represents the exposure pathway of greatest concern. The PAH concentrations in surface sediments at the northern end of the canal were several times greater than concentrations shown in the literature to produce adverse effects in benthic organisms. In addition, even though the risk cannot be precisely quantified, manatees (a federally endangered species) resting on PAH-contaminated sediment may be at risk of increased incidence of lesions and other dermal effects. The risk evaluation found no elevated risk from exposure to surface water or ingestion of food by fish, birds, or marine mammals. The concentrations observed in the southern portion and canal mouth were generally below the range associated with elevated risk to benthic organisms.

1.3.5 RCRA Facility Investigation

A focused RFI was conducted in 2007, to gather additional data to more accurately delineate the extent of sediment constituents, determine sediment depth and geotechnical properties, conduct a mangrove survey along the canal banks, and obtain bathymetric data. Samples were collected at three locations per transect at 26 transects from the vehicle bridge to the mouth of the canal. Field activities were initiated on August 14, 2007, and completed on September 20, 2007. The objective of this RFI was to complete the data collection needed for the identification and development of appropriate corrective measures. Figures 1-4 and 1-5 show the chemistry and geotechnical sampling locations from the 2007 investigation.

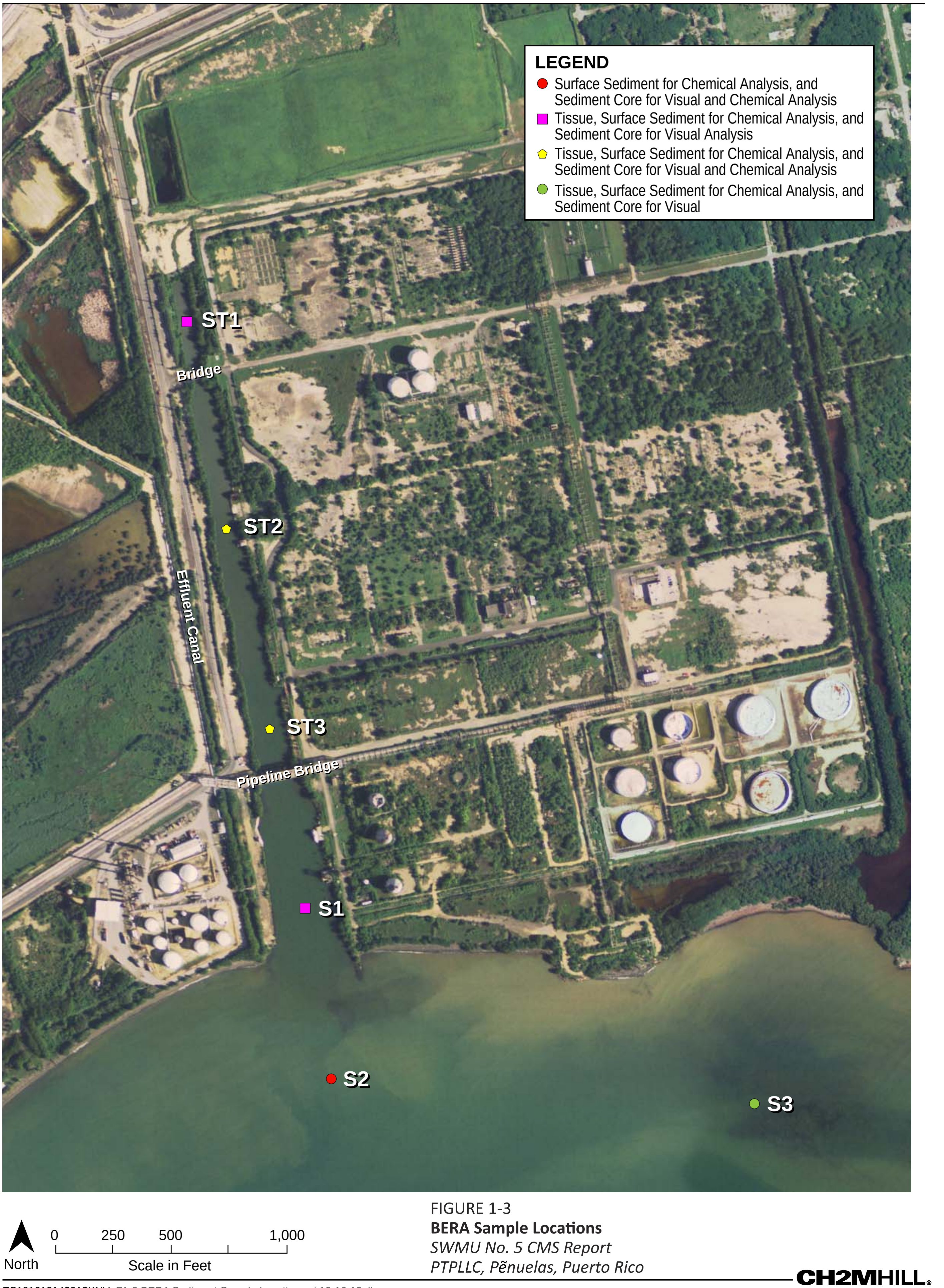
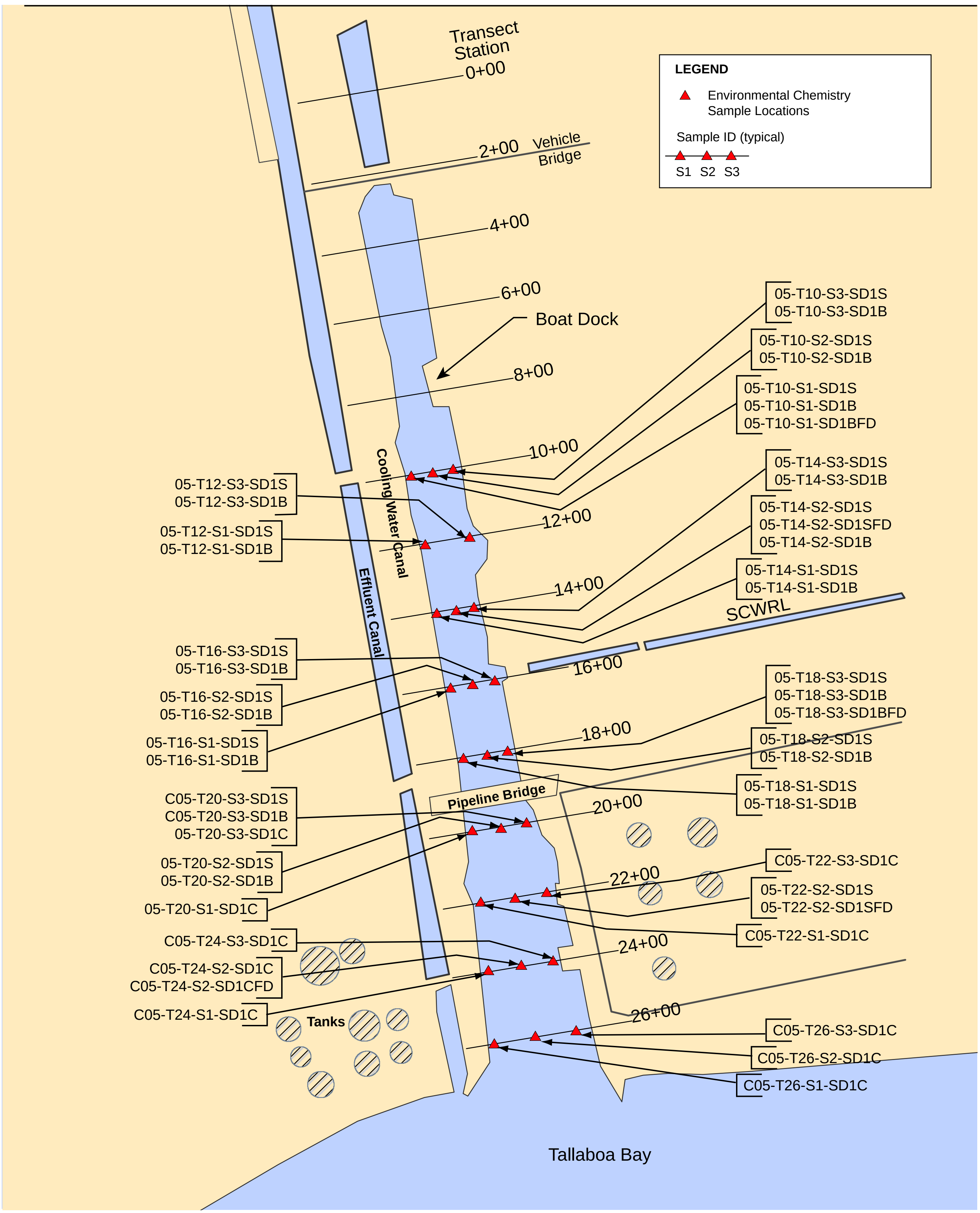


FIGURE 1-3
BERA Sample Locations
SWMU No. 5 CMS Report
PTPLLC, Pẽnuelas, Puerto Rico



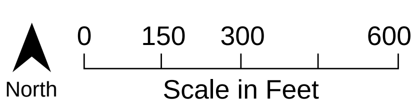


FIGURE 1-4
RFI Environmental Chemistry Sample Locations
SWMU No. 5 CMS Report
PTPLLC, Pẽnuelas, Puerto Rico

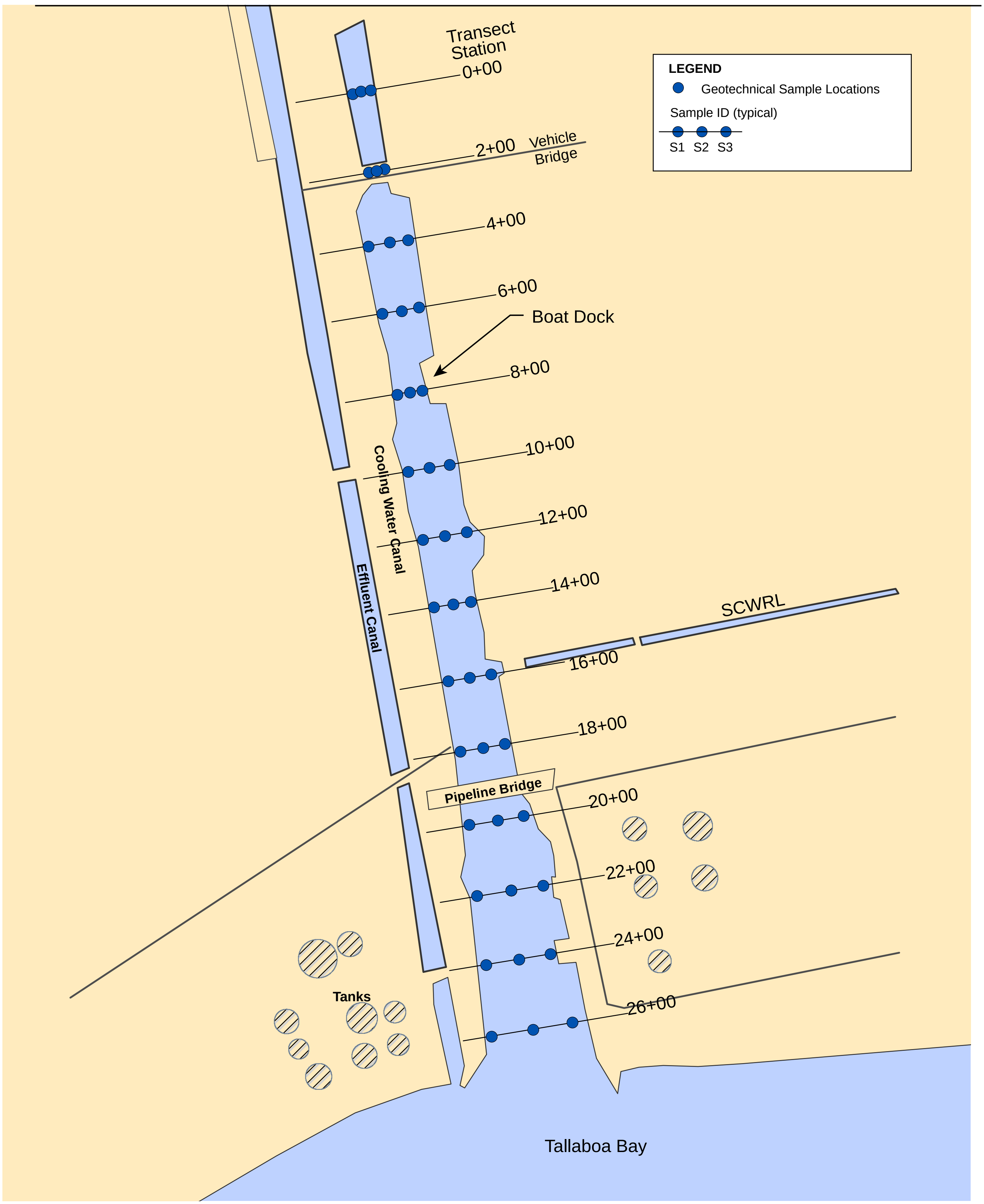


FIGURE 1-5
RFI Geotechnical Sample Locations
SWMU No. 5 CMS Report
PTPLLC, Pẽnuelas, Puerto Rico

CH2MHILL.

ES101612142013KNV F1-5 GeotechnicalSampleLocations.ai 10-16-12 lk

The draft RFI Report was submitted to USEPA in January 2008 (CH2M HILL 2008a) and concluded that the focused RFI sampling results were generally consistent with results obtained in the 2000 Phase I RFI (Union Carbide Corporation 2000) and the 2005 BERA (CH2M HILL 2006). Specifically, the concentrations of dripolene-related constituents are generally highest in the upper 2,000 feet of the CWC, with surface sediment constituent concentrations at levels posing potential risk to benthic invertebrates. Sediment properties are characteristic of fine-grained alluvial deposits and, based on the limited data obtained, sediment strengths are low.

A supplemental investigation of sediment constituents was conducted in accordance with the *Supplemental Sampling and Analysis Plan for Solid Waste Management Unit (SWMU) No. 5, Cooling Water Canal, Transect 20+00 Investigation* (CH2M HILL 2008b). Sampling was performed at Transect 20+00 (T-20) to confirm and validate elevated levels of VOCs in surface sediment at this transect, and total organic carbon (TOC) concentrations at surface and depths to address USEPA comments on the RFI Report (CH2M HILL 2008a). VOC concentrations were below detection limits, similar to those from the 2005 BERA. The elevated VOC values identified during the September 2007 sampling effort may be attributed to potential unaccounted for sample constituents not associated with the T-20 sediment substrate.

The RFI Report (CH2M HILL, 2012a) was finalized and submitted to USEPA in February 2012. The final report results remained consistent with the following earlier conclusions in the draft RFI and BERA:

- In surface sediment, PAHs were the predominant detected parameters
- Based on screening results alone, sediment PAHs in the northern half of the CWC could pose an elevated risk to directly exposed benthic invertebrates
- Surface sediment beginning at T-22 and extending downstream to Stations S2 and S3 in Tallaboa Bay are likely to have negligible risk to benthic invertebrates
- The extent of subsurface constituents downstream to T-20 approximately matches that of surface sediment

The final RFI Report and addenda were approved by USEPA in September 2014.

1.3.6 CMS Work Plan

A draft CMS work plan for SWMU No. 5 (CH2M HILL 2008c) was prepared to set the objectives of the CMS at the site, specific corrective measures to be studied, and the general approach to investigating and evaluating potential corrective measures based on sediment screening results of the draft BERA and RFI reports (CH2M HILL 2006 and 2008a, respectively). The work plan also described proposed treatability studies including laboratory, bench, and field scale tests. The work plan was given conditional approval in October 2011 and a final plan addressing the conditions was submitted November 2011.

1.3.7 Treatability Study

A treatability study (TS) was performed to evaluate potential treatment and containment technologies for the canal sediments, and to address whether the technologies can achieve agreed-upon remedial goals that were based on sediment screening results of the draft BERA and RFI reports. A draft treatability study work plan (TSWP) was prepared to be consistent with the *RCRA Corrective Measures Study (CMS) Work Plan for Cooling Water Canal (SWMU No. 5),* (CH2M HILL 2008c). The draft TSWP was conditionally approved by EPA and the final TSWP was submitted to USEPA in November 2011 (CH2M HILL 2011a). The following Phase 1 and Phase 2 activities were identified in the TSWP:

- Phase 1 field activities (conducted in 2009) included hydrographic and geophysical surveys, groundwater flux investigation in the CWC, sediment and pore water sampling for baseline characterization, and bench scale studies. The bench scale studies were conducted to evaluate the effectiveness of three types of cap (CETCO Reactive Core Mat [RCM], AquaBlok cap, and sand cap) for contaminated canal sediments and to determine related geotechnical properties of canal sediments.

- Phase 2 field activities (conducted in 2012) included pilot scale deployment of three types of caps and filling in a portion of the CWC to evaluate construction feasibility using best management practices (BMPs) and construction monitoring methodologies.

TS investigations were performed as part of the CMS, and the results are included as appendixes to this CMS report:

- Appendix A: *Treatability Study Phase 1 Technical Memorandum* (CH2M HILL2011b)
- Appendix B: *Treatability Study Phase 2 Technical Memorandum* (CH2M HILL 2012b)

As noted at the beginning of this section, the TS was performed to evaluate potential treatment and containment technologies for the canal sediments, and to address whether the technologies can achieve agreed-upon remedial goals that were based on sediment screening results of the draft BERA and RFI reports. However, the agreed upon “remedial goals” referred to in the Treatability Study report were those presented in draft versions of the BERA and RFI reports at that time (2011-2013). The early BERA and RFI goals were associated with ecological risk evaluations and screening criteria directed at assessing potential environmental risks; for example: Tables 4-3 through 4-10 of the RFI (CH2M HILL, February 2012). During the treatability investigations and evaluations, remedial goals were wide-ranging to comprise technologies that could address contaminated sediment. Thus, there is no table in the BERA or RFI presenting specific, numerical remedial cleanup goals.

Subsequent to the draft BERA and RFI reports, a benthic macroinvertebrate community study was performed to further assess risk to benthic organisms and found that no adverse effects to benthic organisms were occurring (as discussed in the following section). Thus, the non-numerical cleanup goals presented in Table 3-1 of this report were developed to address the more specific, non-numeric findings of the benthic study.

1.3.8 Benthic Macroinvertebrate Community Study

Previous investigations have identified surface sediment concentrations of PAHs in the CWC that exceed marine sediment ecological screening values, thus indicating a potential for adverse effects to the benthic macroinvertebrate community. The actual effect of these PAHs on the benthic community at the site was not investigated in the RFI (CH2M HILL 2012a); therefore, a quantitative evaluation was performed to determine whether measureable adverse impacts are occurring in association with elevated PAH concentrations. In 2013, CH2M HILL performed a comparative assessment of sediment chemistry and benthic invertebrate communities in the lower portion of the CWC and background locations. Benthic macroinvertebrate and sediment samples were collected at 15 locations in the CWC and 2 background locations. A weight of evidence evaluation was conducted that included the assessment of surface sediment PAH concentrations, sediment physical characteristics, benthic invertebrate communities, and water quality. These findings were documented in the *Draft Benthic Study Report* (CH2M HILL 2014a) (Appendix C).

As detailed in the benthic study report, the evaluation of multiple benthic community characteristics throughout the CWC below the vehicle bridge indicated no adverse effects compared to background or in response to elevated PAH concentrations. The results of this evaluation, which are based on directly measured ecosystem characteristics and co-occurring contaminant concentrations in the CWC (as opposed to standardized ecological screening values), are used as the primary basis for identifying areas of sediment contamination that warrant corrective measures.

1.4 Regulatory Framework

The CWC is designated as SWMU No. 5 in the RCRA Part B Permit for the facility because of the presence of impacted sediments in the canal. Sediments in the CWC are impacted mainly with SVOCs, including several PAHs, as a result of past site operations.

SWMU No. 5 is the closed NCWRL Canal (stabilized and filled) and the sediments within the remaining, unfilled, portion of the CWC. The canal was used to return noncontact cooling water to Tallaboa Bay. Active remediation to address groundwater impacts for the closed NCWRL Canal as a Group I SWMU currently includes the continued operation of the groundwater recovery well system installed at the closed ILFA.

Sediment within the CWC is being addressed as part of the Group III SWMUs because, as established in the current facility RCRA Part B Permit (USEPA 2003), the sediment is beyond the compliance point for the ILFA, has not been stabilized, is undergoing investigation to identify the extent of the dripolene-related constituents, and may be subject to different corrective action alternative(s).

As described in this section, several investigations of the CWC have been completed up through the benthic study (completed in 2013). The objectives of completing the data collection needed for identifying and developing appropriate corrective measures in the RFI and evaluating specific remedial technologies in the treatability study have been completed.

SECTION 2

Description of Current Conditions

2.1 Physical Setting

Several surveys and measurements were completed to characterize the physical nature of the CWC and the sediments within the canal. These investigative activities are summarized in this section.

2.1.1 Bathymetry Survey

Bathymetric surveys were conducted during the RFI and TS to determine water depths and bottom contours of the canal. This information was used to estimate the potentially required quantity of fill and cap material and develop engineering criteria to design the fill and subaqueous cap systems (as appropriate).

During the RFI, a bathymetric survey of the CWC was performed by ARC Surveying and Mapping, Inc. (2007), by acquiring data along three parallel profile lines (channel center and both sides of the canal) running the length of the canal in a north-south direction (Figure 2-1). Approximately 15 cross-sections (transects in east-west direction) were taken at 100-foot intervals near the previously established transects (T-0 through T-26).

During the TS Phase 1 and Phase 2 field investigations, an additional bathymetric survey was performed in 2009 by CSA International, Inc. (CSA). This more detailed bathymetry was considered necessary to help plan the pilot-scale cap deployment process and equipment selection. During the TS Phase 1 field activity, bathymetric data were collected along the full length of the canal starting from T-4 to T-26 and outside the entrance to the CWC. During the TS Phase 2 field activity, bathymetric surveys focused only on the pilot cap areas between T-4 and T-8. Phase 2 bathymetric data were collected for construction monitoring during pilot scale installation of caps, and to determine pre-cap and post- cap installation changes in the underwater topography in the canal.

Based on these surveys, water depths in the northern end of the CWC range from 1 to 3 feet deep upstream of the vehicle bridge (CH2M HILL 2012b), and increase from 3 feet at the vehicle bridge to 13 feet downstream at the pipe rack bridge. The depth of the canal between the pipe rack bridge and the canal entrance ranges from 12 feet to 16 feet. A shoal with water depth less than 5 feet was observed at the canal entrance; beyond this shoal, the water depths increase to greater than 20 feet entering into Tallaboa Bay (CSA 2009).

2.1.2 Side Scan Sonar Survey

Side-scan sonar surveys were performed by CSA during the TS Phase 1 (CSA 2009) and Phase 2 (CSA 2012) field investigations to define the sediment surface in the canal and to detect obstructions on the canal floor that may hinder future possible cap installations. Side-scan sonar survey data supplemented the bathymetric survey and provided higher resolution to provide cap deployment details. During the TS Phase 1, the side-scan sonar survey was conducted for the full length of the canal from T-4 to T-26; however, in Phase 2, the survey was focused only in the pilot test cap areas between T-4 and T-8.

The Phase 1 survey images show that the middle of the CWC is fairly flat and featureless for its entire length, with steep canal walls present along both sides (CSA 2009). Features noted include the boat house bulkhead and fire control pump areas, a small canal running west to east and perpendicular to the main canal (otherwise known as the South Lateral Return Canal), supports for the pipe rack bridge, and a prominent bottom feature on the west side of the canal south of the pipe rack bridge. This bottom feature was noted to be a rise of approximately 6 feet above the surrounding bottom. Wooden pilings along the east side of the canal and corrugated sheet piling along the west side of the canal were noted at the canal entrance.

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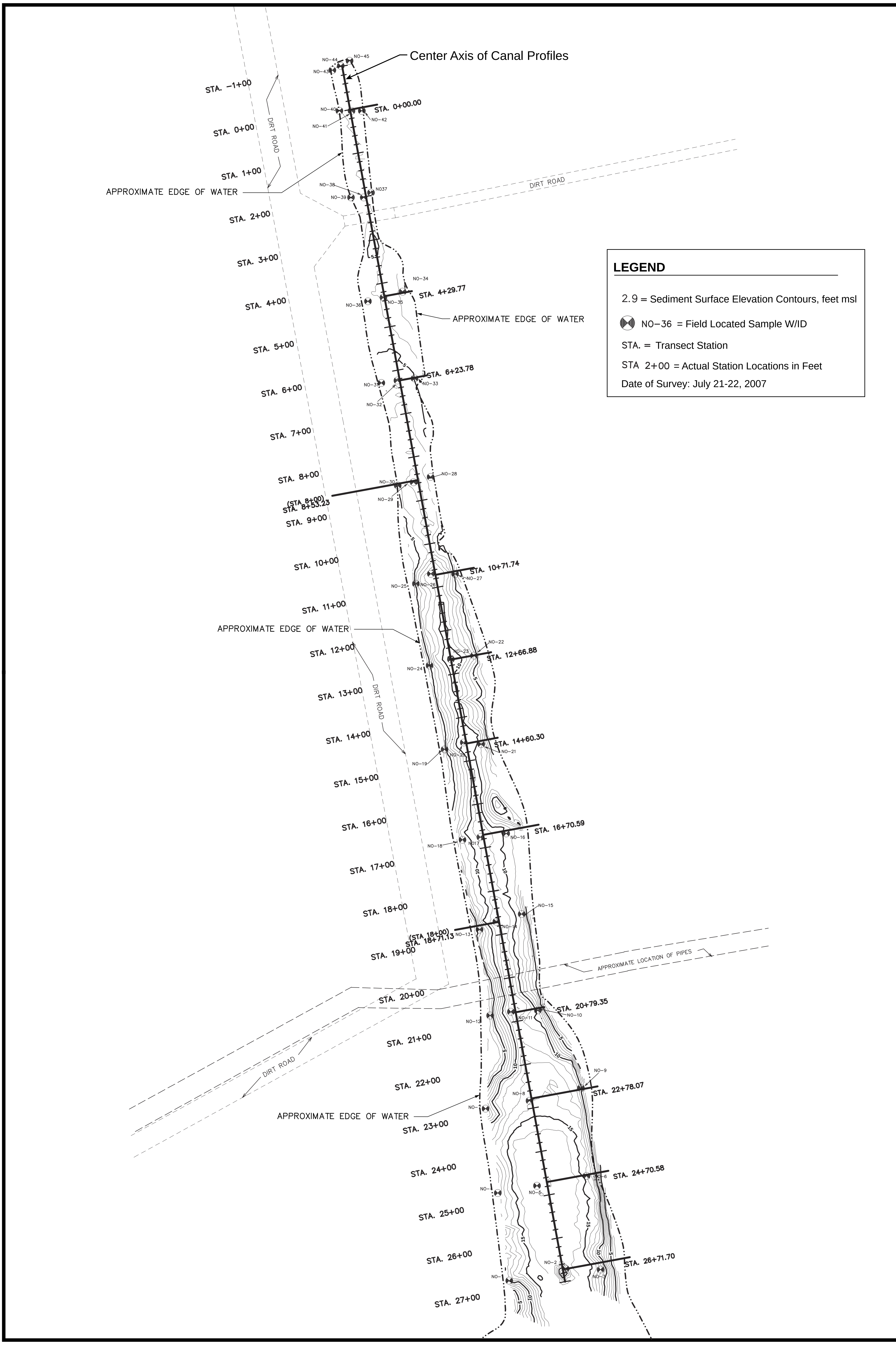

FIGURE 2-1
Bathymetry Contour Map
SWMU No. 5 CMS Report
PTPLLC, Pẽnuelas, Puerto Rico

CH2MHILL.

ES101612142013KNV F3-5 BathymetryContourMap.ai 10-16-12 lk

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The TS Phase 2 side-scan sonar survey was conducted for construction monitoring to evaluate the pilot scale cap installations. The pre-cap and post-cap installation side-scan sonar images illustrated canal bottom surface and some features of the installed caps, such as folds in the CETCO RCM and impressions of test buckets in the AquaBlok and sand cap areas (CSA 2012).

2.1.3 Sub-bottom Profiling

Sub-bottom profiling was performed by CSA during the TS Phase 1 field investigation to evaluate the layers of the softer sediments below the water/sediment interface and lying on top of the harder sediment substrates.

The sub-bottom profiles illustrate that the profile running very close to the western side of the canal traversed five prominent shallow outcrops projecting from the canal bank. The profiles along the center and eastern side of the canal depict prominent features including outcrops just south of the pipe rack bridge, an outcrop just north of the small side canal, a buildup of sediment at the discharge area at the fire control pumps located along the southeast shoreline of the canal, and a smaller area next to the bulkhead at the boat house (CSA 2009). These outcrops were not specifically characterized, but represent a firm material distinct from the softer sediment horizon. Observations at the outcrop near the pipe bridge indicate a very hard material.

2.1.4 Acoustic Doppler Current Profiler

An Acoustic Doppler Current Profiler (ADCP) was deployed during the TS Phase 1 field investigation to measure water current profiles in the CWC for a range of water depths. The water current profile data in the canal were collected to evaluate erosion and scouring potential of sediments and cap material, and to determine armoring requirements for future possible caps.

The highest current speeds (in excess of 0.5 knot [kn]) were measured at mid-water depths related to water released from the fire control pump discharge pipe located 275 feet north of the ADCP location. With the exception of these higher "spikes," water current speeds at the near-bottom and mid-water levels in the canal averaged 35 millimeters per second (mm/s) (0.07 kn). Near-surface current speeds averaged 40 mm/s (0.08 kn), except during ebb and flood tide stages, when current speeds as high as 100 mm/s (0.2 kn) occurred (CSA 2009).

The nearest National Oceanic and Atmospheric Administration (NOAA) tide station is at Magueyes Island, about 20 miles west of the site. Daily tidal fluctuations range from as little as a few tenths of a foot to about 1.2 feet. Data from September 2011 through August 2012 indicate typical extreme tides range from about -0.4 to 0.8 feet msl. In late August 2012, the extreme high tide was nearly 1.5 feet msl, likely caused by Tropical Storm Isaac.

2.1.5 Groundwater Flux Measurements

During the TS Phase 1 and 2 field investigations, seepage meters were deployed to measure water seepage across the sediment/water interface separating groundwater below the canal and surface water in the canal. Seepage meters provided data for groundwater flux in the canal to determine an advection rate at which constituents can pass through the sediments and permeable portions of a future possible cap.

During TS Phase 1, four meters were deployed at different locations for a wider characterization of surface water - groundwater exchange. The results showed flux rates at the site varied from 0.020 centimeter per day (cm/d) to 0.295 cm/d. The Phase 1 results were considered preliminary because the meters were deployed for relatively short periods of time and measured small changes in water volume.

During TS Phase 2, only one out of three seepage meters was successful in obtaining readings and showed upward flux of 0.001 centimeter per year (cm/yr) in the first 72 hours followed by (–)0.0139 cm/yr in the following 48 hours. The positive upward flux followed by negative downward flux can be attributed to the tidal action and other field activities from barge and boat movement at the site.

2.2 Sediment Properties

Sediment sampling was performed during the BERA, RFI, TS Phase 1, and benthic study tasks. During the BERA, sediment chemistry samples were collected from a total of seven stations from within and outside the mouth of SWMU No. 5 (including a reference station), and were positioned to provide data on the horizontal and vertical extent of COPCs.

RFI sediment sampling was conducted for chemical and geotechnical characterization of the CWC. Sediment chemistry stations and geotechnical stations were co-located where possible to provide for sampling efficiency and the correlation of geotechnical and chemical data.

TS Phase 1 sediment sampling was focused on pilot test areas between T-0 and T-2, and T-4 and T-8 to determine the existing chemical and geotechnical conditions in those areas. Cone penetrometer tests (CPTs) were performed for physical characterization during this phase along the length of the canal.

The benthic community study was conducted at 15 surface sediment stations within the CWC and at two background stations near the mouth of the CWC, and included the collection of co-located sediment chemistry and physical parameters (TOC and particle size), along with benthic community sampling.

These data are described in this section.

2.2.1 Physical

Based upon data from the RFI geotechnical characterization, sediment materials were found to be predominantly organic clays overlying a thin layer of silty sands overlying limestone. The material was primarily classified as silty clay (CL or CH), except near the southern end of the canal where the sediments were silty sands (SM), or highly organic clays and silts (OL).

The TS Phase 1 CPT data indicated sediments contained occasional lenses of high resistance, and generally increasing resistance with depth. The sediment samples were classified as highly plastic organic silt with high liquid and high plastic limits. The moisture content data indicated that the silt should be considered a liquid for soil classification purposes. The loss on ignition (LOI) test results indicated an organic content of approximately 10 percent, which is not considered to be highly organic.

Additional TS Phase 1 laboratory geotechnical data performed by the University of New Hampshire (UNH), and the results referenced previously were assembled to provide a general summary of site sediment properties (Table 2-1).

TABLE 2-1
Summary of Sediment Physical Properties
CMS, PTPLLC, Peñuelas, Puerto Rico

Sediment Property	Representative Values
Thickness (above refusal)	Less than 8 feet above the vehicle bridge and up to 40 feet at Station 20+00
Classification	Fine grained slightly organic silty clay with some silty sand
Consistency	Very soft to soft
Moisture Content	Moderate to very high, sometimes > 100 percent
Plasticity	Moderately to highly plastic
Specific Gravity	2.436
Unconfined Compressive Strength (Torvane)	20 to 33 pounds per square foot (psf)
Direct Shear Strength	Cohesion = 0; Ø = 38°

TABLE 2-1
Summary of Sediment Physical Properties
CMS, PTPLLC, Peñuelas, Puerto Rico

Sediment Property	Representative Values			
Consolidation Parameter	e	γ	Cc	Cr
0-1 foot deep	4.5	78.7	0.9769	0.043
1-3.5 feet deep	4.0	80.3	0.9769	0.043
3.5-12 feet deep	3.5	82.3	0.9769	0.043
Settlement (Consolidation) of Underlying Sediment Expected Due to Cap/Fill Placement				
Proposed Cap/Fill Thickness (inches)	6	12	24	
Predicted Settlement (inches)	2.4	4.8	9.6	

2.2.2 Chemical

During the BERA, SVOC COPCs were detected at each of the canal stations and outside the mouth. Sediment samples represented 0 to 18 inches. Highest concentrations were measured within the northern half of the canal. Data indicated that sediment constituents from the upgradient portion of the canal had not significantly migrated downstream to the canal mouth or beyond. During the RFI, it was noted that the concentration distribution was higher in the northern portion of the CWC at T-10. Concentrations were greater midway down the CWC at T-16 and T-18, and then decreased toward the mouth at the southern portion. Sediment samples were collected at 0- to 2-foot depths. In general, PAH, non-PAH SVOC, and VOC concentrations were higher in subsurface sediments than in surface sediments. The TS Phase 1 surface sediment samples, collected at 0- to 6-inch depths, were analyzed for PAHs and general chemistry to determine the existing constituents in the pilot test areas. These areas exist in the northern portion of the CWC and results indicated high levels of PAHs similar to those reported in the BERA and RFI. The chemical characteristics of the CWC sediment are summarized in Table 2-2.

TABLE 2-2
Summary of Sediment Chemical Properties
CMS, PTPLLC, Peñuelas, Puerto Rico

BERA 2006	
Northernmost locations ST-1 and ST-2	In upper 18 inches samples, visible chemical constituents were noticed with a pure black, sticky material with inclusions of red colored chemical oozing from the cores
Location ST-2	The 12 to 18-inch segment contained elevated concentrations of benzene (13 milligrams per kilogram [mg/kg]), ethylbenzene (530 mg/kg), m+p xylene (360 mg/kg), o-xylene (110 mg/kg), and toluene (17 mg/kg) Total SVOC concentrations ranged from 91 mg/kg at the surface to 13,411 mg/kg at 12 to 18 inches
Downstream Location ST-3	SVOC concentrations decreased ranging from 7.0 mg/kg at the surface to 9.3 mg/kg at 12 to 18 inches
RFI 2012a (Table 4-2)	
Between T-10 and T-22	The highest surface sediment PAH concentrations (0 to 1 feet) were reported at stations T-10 (591 mg/kg) and T-14 (498 mg/kg) with detects as far south at T-20 (49.5 mg/kg). Total non-PAH SVOC concentrations in surface sediments ranged from 1.912 mg/kg at T-20 to 4.21 mg/kg at T-22.

TABLE 2-2
Summary of Sediment Chemical Properties
CMS, PTPLLC, Peñuelas, Puerto Rico

	The highest subsurface PAH concentration was seen at T-10 (3104 mg/kg) and reported as 863 mg/kg at T-16 and 389 mg/kg at T-18. The highest subsurface non-PAH SVOC concentration was measured at T-10 (143 mg/kg). Similar to the PAH concentration distribution in subsurface sediment, non-PAH SVOC concentrations decreased toward the southern portion of the CWC, with a spike midway at T-18 (25.33 mg/kg). Total VOC concentrations in surface sediment ranged from 0.042 mg/kg at T-12 to 0.104 mg/kg at T-22 with a potential outlier at T-20 (36.36 mg/kg). Supplemental sampling performed at T-20 to confirm and validate elevated levels of VOCs showed that VOC concentrations were below detection limits at this location. The highest subsurface VOC concentration was seen at T-10 (413.1 mg/kg). Similar to PAH and SVOC concentration distribution in subsurface sediment, VOC concentrations decrease towards the south portion of the CWC with a spike midway at T-16 (35.25 mg/kg).
TS Phase 1 2011a	
Between T-0 and T-2	Total PAHs in surface sediments (0 to 6 inches) at one station was reported as 431 mg/kg, moisture content as 56.3 percent, and TOC as 70,300 mg/kg.
Between T-4 and T-8	Total PAHs and general chemistry were analyzed for surface sediment samples (0 to 6 inches) obtained from six locations between T-4 and T-8. The PAH concentrations ranged from 173 mg/kg to 1,203 mg/kg, moisture content ranged from 61.3 to 71.3 percent, and TOC ranged from 31,400 mg/kg to 76,300 mg/kg.
Benthic Study 2013	
Between T-4 and T-20	Total PAH concentrations (representing 15 stations) were highest at the upgradient (northern) end and significantly declined in the downgradient (southern) direction, ranging from 190.4 to 2.8 mg/kg. TOC ranged from 15,900 to 47,700 mg/kg, and averaged 25,250 mg/kg. Average particle size was 0.2 percent gravel, 14.1 percent sand, 58.8 percent silt, and 26.9 percent clay.
Background at T-27	Total PAH concentrations were low, ranging from 0.15 to 0.22 mg/kg at these background locations. TOC ranged from 31,500 to 36,900 mg/kg, and averaged 34,200 mg/kg. Average particle size was 3.5 percent sand, 66.8 percent silt, and 29.8 percent clay.

2.2.3 Dripolene Product

An investigation of the CWC sediments was performed in 2007, as reported in the RFI (CH2M HILL 2012a), using samplers and probes to characterize the sediment profile, collect sediment samples, and determine depth to refusal. A Geoprobe rig was deployed to drive core barrels into the sediment downstream of the vehicle bridge, and a KB hand corer was used upstream of the vehicle bridge (shallow water depth) to retrieve core samples to observe the presence of dripolene product. During the Phase 1 TS in 2009, plastic tubes were pushed into the sediment to retrieve samples. These RFI and TS core samples were evaluated in the field to visually determine the presence of dripolene product, and the results were recorded as presented in Appendix G of the RFI and the TS Phase 1 report (Appendix A).

Dripolene product was encountered in nine (about 27 percent) of the 33 coring locations in the upper 2,000 feet of the canal. At these nine locations, dripolene was found at and near the sediment surface, down to depths of up to 18 feet below sediment surface (bss). Dripolene was encountered to depths of at least 8 feet bss in all but two of the nine locations. This widespread distribution both vertically and horizontally provides a significant challenge to any product removal alternative because of the large volume that would require excavation.

2.3 Pore Water Concentrations

During TS Phase 1 activity, pore water sampling was conducted in the pilot scale capping study areas between T-2 and T-8, toward the northern part of the CWC. Pore water was analyzed for PAH concentrations to evaluate the concentration and mobility of dissolved constituents in the surface/groundwater system and potential capping/fill system.

The pore water concentrations of PAHs exceeded surface water ecological screening values (ESVs) for at least one PAH compound in all the samples. Some of the pore water samples were also analyzed for metals and general chemistry including TOC. The total PAH concentration ranged from 10 micrograms per liter (µg/L) to 12,289 µg/L, and TOC ranged from 0.5 milligrams per liter (mg/L) to 13.2 mg/L.

2.4 Constituent Summary

The CWC physical and chemical site data as summarized previously, and further detailed in the BERA, RFI, and benthic study reports, are summarized as follows:

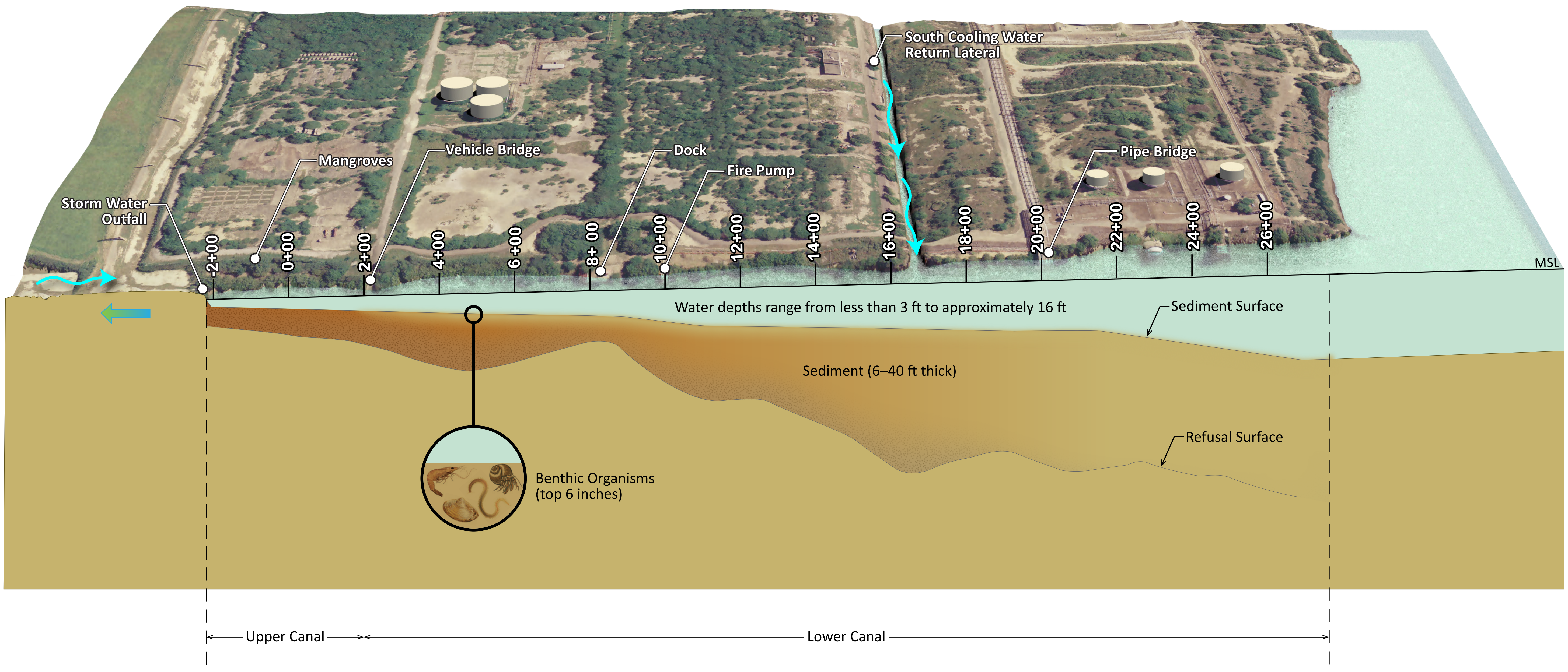
- Currently, groundwater flux into the CWC is very small, especially in the northern portion. Future increases in flux into the canal in this area may be possible if operation of the groundwater extraction system upgradient (north-northeast of the northern terminus of the canal) is terminated.
- Water depths and sediment thicknesses above refusal generally increase from north to south; water depths range up to 13 feet at the pipe bridge, and the measured sediment thicknesses range from 4 to 40 feet. Water depths at the canal entrance are up to 16 feet.
- Currents are very small in the canal (0.2 kn); average tidal ranges are about 1 foot.
- Free product (dripolene) intermittently occurs throughout the upper 2,000 feet of the canal, and is more prevalent in the northern portions. It was visible in most sediment cores within the upper 8 feet, and as deep as 18 feet bss in one sample.
- The highest surface sediment PAH concentrations (0 to 0.5, and 0 to 1 foot) in the CWC occur from T-4 through T-14, with lesser detections as far south as T-20. The levels of surface PAH constituents decrease toward the mouth of the canal, approaching nondetectable levels in the canal within 400 feet of the mouth. Total non-PAH SVOCs in surface sediment appeared to be evenly distributed down the length of the canal.
- The highest PAH concentrations (3,104 mg/kg) in subsurface sediment (1 to 2 feet) were measured at T-10. Concentrations then drop several orders of magnitude at stations T-14 (112 mg/kg), then rise at T-16 (863 mg/kg), and then drop at T-20 (6.64 mg/kg) (as reported in Table 4-2, RFI, CH2M HILL 2012a). T-16 is adjacent to the SCWRL Canal. Similar trends are evident with VOC concentrations in subsurface sediment.
- RFI COPC concentrations in CWC surface water were previously evaluated in the *Management-Level Ecological Risk Assessment (ERA)* (URS 2000), and summarized in the BERA (CH2M HILL 2006). The results, which demonstrated that all surface water COPCs were below detection limits and posed no unacceptable risk to ecological receptors, were submitted to USEPA in 2003. USEPA indicated its acceptance of the surface water analysis on February 6, 2004.
- Based on differences found in sediment constituents and potential receptors in the ecological risk evaluations, the canal was divided into two sections for remedial consideration (Figure 2-2): the upper canal (above vehicle bridge) and the lower canal (below vehicle bridge).

2.5 Conceptual Site Model

A conceptual site model (CSM) has been developed to represent the scope of constituents at the site, the environmental setting, and ecological receptors identified as potentially at risk from surface sediment constituent exposure. The primary ecological receptors are the directly exposed populations of benthic invertebrates living within the surface of the cooling water canal sediment, such as marine polychaetes, crustaceans, and mollusks. Potential risks to other ecological receptors, such as fish, birds, and dolphins, were found to be low, and therefore are not depicted in this CSM. The CSM is depicted graphically in Figure 2-2.

A preliminary human health CSM was developed during the RFI and was based upon available site information and potential exposure pathways (CH2M HILL 2012a). The direct exposure points were identified as sediments and surface water, and indirect via fish for recreational fishers/trespassers and environmental workers. Because a guard is present 24 hours a day, 7 days a week, recreational fishing and trespassing exposure scenarios at SWMU No. 5 were determined to be extremely unlikely and excluded as exposure pathways.

The environmental workers may contact sediment while conducting sampling and remediation activities, but are health and safety trained and use applicable personal protective equipment (PPE) for the suspected/known chemicals present. It is standard practice to exclude hazardous waste workers from risk assessments for RCRA sites.



LEGEND

Surface Water

Groundwater

Concentrations of Dripolene-related Constituents

Higher→Lower

NOTES

1. Exaggerated vertical scale below MSL.
2. Dark to light brown shading in sediment represents decreasing concentrations of dripolene-related constituents. Tan color represents absence of significant concentrations.

FIGURE 2-2
Conceptual Site Model
SWMU No. 5 CMS Report
PTPLLC, Peñuelas, Puerto Rico

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SECTION 3

Media Cleanup Standards

The purpose of this CMS is to address the current and future potential risks to benthic organisms in surface sediment in the CWC and the potential future risk to the environment if deeper sediments are disturbed.

The physical conditions of the canal vary considerably between the sections above and below the vehicle bridge; these sections are addressed as separate physical units as follows:

- Above the vehicle bridge (upper canal), the water depth is shallow (less than 3 feet)
- Below the vehicle bridge down to the pipe bridge (lower canal), the depths are 3 feet or greater

This physical division and the proximity of the upper canal to the dripolene sources and other site constituents suggest a higher level of protection is required for the upper canal. Thus, the goals for the two canal sections are addressed separately.

3.1 Risk Evaluation Summary

The risks posed by contaminated sediments at SWMU No. 5 are summarized as follows:

- No elevated risk was found for aquatic organism exposure to surface water, or for higher aquatic food chain organisms (such as semi-aquatic birds and mammals) ingesting prey species from the canal, including aquatic plants, invertebrates, and fish.
- Surface sediment constituents at concentrations that can pose potential risk to benthic invertebrates may occur within the upper 350 to 400 feet of the canal (above the vehicle bridge). This zone was not studied in detail and presumed to consist of similar constituents as the filled in portions of the former NCWRL Canal.
- Surface sediment constituent concentrations (upper 6 inches) in the CWC below the vehicle bridge present no adverse impacts to the benthic community. Dermal exposure of surface sediment to manatees was found to have a potential, though uncertain, level of risk. Manatees have not been observed resting in the CWC during monitoring; therefore, exposure is unlikely to occur.
- Benthic invertebrates are not exposed to subsurface sediments; therefore, there is no current ecological risk. Aquatic organisms could become exposed to subsurface sediment following events such as dredging, sediment manipulation associated with a remediation activity, or a significant storm event (hurricane) that could scour surface sediment from the canal. Numerous named tropical storms and hurricanes have directly impacted the southwest coast of Puerto Rico over the past 50 years, including the PTPLLC site; eight storm events have occurred since the late 1980s (HurricaneCity.com, 2014). Despite the occurrence of these storms and their possible impact on the canal, the constituents of potential concern have not migrated beyond the northern two-thirds of the canal or into Tallaboa Bay.

Subsurface sediments more than 2 feet bss are known to contain sporadic pockets of sediment containing free dripolene product. During sediment coring/sampling in areas where these pockets were encountered, small sheens on the water surface were observed as the coring device was removed from the sediment and brought to the surface to extract sediment cores. The sheens were relatively small, no more than a few feet in diameter, and they dissipated within a day. During Treatability Study activities, no sheens were observed during activities that included deployment of pilot-scale subaqueous caps south of the vehicle bridge in the canal, and a pilot-scale backfilling operation conducted north of the vehicle bridge during which backfill was pushed into the canal from the bank covering the canal sediment.

3.2 Media Cleanup Goals

Remedial alternatives will be developed to reduce the ecological risk by eliminating exposure of benthic organisms to the impacted sediment in the upper canal (upper 350 to 400 feet of the canal). The specific goal is to minimize or block the contact of ecological receptors with impacted sediments in the upper canal, and to control the migration of highly contaminated sediments within the upper canal. The remedial goal for subsurface sediments in the lower canal is to prohibit activities that could result in future migration of subsurface contaminated sediment to surface sediments or other water bodies. The goals are summarized in Table 3-1.

TABLE 3-1
Sediment Remedial Goals
SWMU 5 CMS, PTPLLC, Peñuelas, Puerto Rico

Remedial Goal	Upper Canal Surface Sediments	Upper Canal Subsurface Sediments	Lower Canal Surface Sediments	Lower Canal Subsurface Sediments
Protect benthic organisms	X		No impairment	
Prevent migration of contaminated sediment	X	X	No impairment	X

Upper canal - north of vehicle bridge.
Lower canal - south of vehicle bridge.

Cleanup activity best practices include the following:

- Prevent downgradient migration of impacted sediment
- Minimize net impact to shoreline mangrove vegetation
- Promote the growth and diversity of post-remedy benthic communities
- Maintain surface drainage of the surrounding lands

SECTION 4

Identification, Screening, and Development of Corrective Measure Alternatives

4.1 Technology Evaluation

Preliminary remedial technologies have been developed to address remedial site goals presented in the previous section. Risks to subsurface sediments in the lower canal are currently addressed by ongoing institutional and engineering controls including restricted canal access (fencing, security patrols) and industrial worker controls (work permitting, monitoring); therefore, the identified remedies address only the upper canal sediments.

Candidate technologies were developed in the CMS work plan to address possible combinations of the following technologies:

- Filling the canal
- Subaqueous capping of impacted sediments
- Vertical subaqueous retaining wall
- Removal, dewatering, and disposal of impacted sediments

These preliminary candidate technologies were further evaluated and refined using information from the treatability studies and field scale pilot tests to identify viable and effective corrective measures. In addition, in-situ and ex-situ sediment treatment technologies were also evaluated in combination with removal, dewatering, and disposal of impacted sediments.

It is important to note that, at this stage of the CMS, the candidate technologies may not be considered a complete corrective action alternative. Rather, they are typically combined to form corrective action alternatives in the subsequent stages of the CMS, as described in Section 4.2. For example, the fill and passive cap technologies may be combined to form a single capping alterative.

The following sections present the evaluation of each of the aforementioned candidate technologies.

4.1.1 Filling the Canal

This technology involves placing clean fill material in the upper canal to a thickness ranging from approximately 1 foot up to the level of the surrounding ground. Using appropriate fill material, the thickness described would be sufficient to serve as protective material (similar to a cap) and would also provide for drainage and maintain enough water depth to sustain mangroves. A channel for surface drainage would be provided. Erosion control material would be provided to stabilize the fill and drainage area. Fill over contaminated sediments is a viable technology that would be protective of potential site receptors (benthic organisms). General material options for fill include offsite and onsite materials. Materials within certain areas of the PTPLLC were investigated for suitability as fill material in 2006 (CH2M HILL 2007). These areas within the PTPLLC facility included the earthen dikes surrounding dredge material disposal areas, including the Dredge Material Area West of Wastewater Treatment Plant (SWMU No. 14) and the Northwestern Puntilla Site (NPS) located adjacent to and southwest of SWMU No. 11. SWMU No. 14 is a No Further Action status site.

Based on soil borings and geotechnical and analytical testing, some of the dike material from these areas was considered potentially useable, but concerns over ecological impacts, presence of fine grain particles, and need for the dikes as a shoreline buffer challenge the viability of this potential material. The concern over ecological impacts is limited to SWMU No. 11 where low concentrations of benzo(a)anthracene and benzo(a)pyrene were detected in the soil in previous RFIs (UCC 1991 and UCCLLC 2000). Based on the findings of a screening level risk assessment (UCCLLC 2000), the levels of these compounds were low enough such that institutional controls consisting of limiting site access and a deed restriction were approved as the corrective action by the USEPA for this SWMU (as stated in the current RCRA permit for the PTPLLC facility). However, due to the uncertainty associated with the potential ecological impacts resulting from the use of soil from this SWMU as backfill in the canal, and the need to modify the current RCRA permit to change the status of this SWMU, the use of soil from this SWMU as backfill was excluded from further consideration.

A review of the particle size gradations of samples from the dike material in the NPS and SWMU No. 14 areas indicate 15 to 30 or more percent passing the No. 200 sieve. Though potentially suitable as fill, these fines would be problematic for use as cap or fill material because of the difficulty of placing fine-grained material through the water column, and because they are physically unsuitable for capping or for the lower load-bearing levels of backfill. In addition, significant processing (screening) of the soils from these areas would be required to remove plant material and roots because the dikes are completely overgrown by small to medium size bushes. For these reasons, these factors would need to be carefully considered in the final selection and design of corrective action alternatives that would include backfilling or capping with soil from these areas.

Offsite (commercial) materials have been used at the PTPLLC facility for fill, cover, erosion control, and other applications for many years. Historically, the evaluation of commercial material suitability for application in a RCRA unit (such as a cover material or drain material for a SWMU closure), included pre-construction laboratory analyses of the material for chemistry parameters, and an evaluation of the results for suitability with respect to soil screening levels. Caliche and sand sources have been identified, were found to be acceptable for fill in these previous projects, and are expected to be available for CWC remediation. In addition, the fill materials will also need to be evaluated for suitability in propagating mangroves, as this may be an integral component of the selected corrective action. This evaluation would be performed during the design phase of the corrective action.

Fill, in general, would require placement in relatively thin lifts (6 to 12 inches) to minimize uneven loading on the soft sediments, which could result in mud waves. Placement would be performed by a long reach backhoe (excavator) operating from the bank or from a shallow draft barge. Geotextile or membrane options would help support placement of fill on soft sediment. Fill material would be stockpiled on the bank or on a material barge. A real time monitoring system would be required to verify placement thicknesses and control fill progress.

In situ stabilization of soft sediment prior to fill was evaluated to improve stability and support for membrane/fill installation. Stabilizing would require dewatering of the canal, treating and disposing of the water, mixing the sediment with cement/caliche in place, and then implementing the membrane/fill options. Because of the large volume of water that would require treatment and the additional exposure risk during stabilization (direct contact with dripolene), this in situ stabilization option is not considered further.

4.1.2 Geotextile Mat

A geotextile would be applied to areas receiving fill material that is placed in a bulk state. Placing bulk materials (filling and some capping options) on soft sediment could cause uneven loads that could exceed the bearing capacity of the soft sediments. This would cause instability during and after the filling operation. Placement of a geotextile prior to placing bulk material would help bridge over the soft materials and provide a more stable “platform” for the fill or cap. The geotextile would be permeable and have sufficient strength for this application. Though the geotextile may not completely eliminate uneven settlement, it would greatly improve the uniformity and stability of fill/cap material placement.

Typically, a geotextile consists of a permeable woven or nonwoven sheet of plastic yarn supplied in rolls about 12 feet wide. It would be placed across the canal in overlapping panels on the sediment surface prior to bulk material placement. The geotextile panels would be submerged and held in place with sand bags or small piles of fill material.

Geogrids, similar to geotextiles, are also used to provide material support on soft sediment, and may be considered a special option during design. Geogrids are potentially much stronger per unit area than geotextiles and would provide a more effective bridge over soft materials in situations where geotextile strength is insufficient. However, a geogrid does not typically provide any significant separation between the soft materials and the overlying fill.

Geotextiles are also used to support and provide separation for erosion control stone material place on a cap or fill surface, especially in drainage ways.

4.1.3 Active Capping

This technology includes the placement of active (also referred to as reactive) cap material, over impacted sediment to chemically immobilize pore water constituents that migrate up through the sediments. Reactive materials like organophilic clays and activated carbon have been used to sequester organic constituents and minimize advective transport. Traditionally organophilic clays have been employed for remediation of nonaqueous phase liquid (NAPL) impacted sediments and activated carbon is normally used to increase the sorption capacity for dissolved constituents in sediments. Organophilic clays are less sorptive than activated carbon for dissolved phase constituents but have significant sorption capacity for NAPL in the contaminated environment (free product) (Reible et al. 2011). Organophilic clay works best for low soluble organics and has noncompetitive adsorption; whereas, with activated carbon there is competitive absorption and NAPL can cause fouling (Olsta 2012).

In the lower canal, an active cap would not be applicable as sediments are stable and surface sediments are not affecting the benthic communities.

In the upper canal, specific organophilic clay and activated carbon cap options include bulk placement of reactive materials, organophilic clay or activated carbon adhering to aggregate such as AquaBlok (AquaGate) technology, and reactive material filled in between geotextiles such as a CETCO RCM. Fine materials would be difficult to install from the banks in the upper canal due to small thickness tolerances and verification challenges, and issues with floating equipment access.

In 2009 CH2M HILL performed bench scale studies to determine the effectiveness of the reactive materials followed by pilot scale implementation in 2012 to evaluate construction feasibility using BMPs and construction monitoring methodologies. The pilot scale implementation demonstrated challenges for delivering the reactive caps on top of soft sediments below the water surface, difficulties of working and filling directly on the soft sediment, and limitations of equipment available at the site. Results showed that proper capping equipment and reactive cap material both need to be shipped to the site from the U.S. mainland.

Successful application of bulk organophilic clay or RCM in the shallow water of the upper canal was not tested in the treatability study and would be problematic because of floating equipment access, and difficulties with application and verification. RCM installation in the upper canal would be possible, but RCM would provide no advantage over the more impervious membrane, cap, or fill options as a barrier to dripolene migration. The capacity required to sequester dripolene and pore water concentrations of PAHs is unknown and could be quite large; therefore, active capping is not considered further for CWC sediment.

4.1.4 Passive Capping

This technology includes the placement of a layer of inert, nonreactive material over contaminated sediment to physically isolate the contaminated solids from aquatic organisms, and to immobilize and contain the contaminated solids and other cap layers. Material options include sand, fine grained material (native material or caliche), geomembrane, and AquaBlok.

Sand is an effective physical barrier for benthic and other organisms from direct contact with the impacted sediments. If relatively free of fines, it can be placed effectively through the water column. Since it does not provide any significant chemical adsorptive capacity by itself, it is often combined with other cap options to provide a bioturbation layer and/or physical containment of the active layers.

Installation of fine grained material such as silty or clayey sands can be problematic because of segregation and drift of the finer materials, turbidity in the water column during placement, and instability of placed fines on the bottom. Normally, installation of these fine grained materials is performed from floating equipment to place the material in uniform layers and due to the physical constraints of the canal, it would be difficult to deploy and properly maneuver floating equipment to install the fine grained material. Fine materials would be difficult to install from the banks in the upper canal due to small thickness tolerances and the ability to accurately verify the in-place thickness of the material. However, finer grained cap materials have benefits such as reduced permeability (for pore water) and increased sorption. If fines are placed as an initial layer under a low energy and low flow environment (in a slurry form) followed by placement of coarser, properly graded sand or gravel material for erosion protection and to hold the fines in place, this could be a viable capping option.

A geomembrane is a plastic sheet of impervious material that can be placed to provide a cap that is impervious to pore water flow. Because of its buoyancy and large panel sizes, it can be difficult to place underwater on the sediment surface, but it is possible to install a plastic liner from the banks given the width of the canal. Provisions for release of gases occurring beneath the membrane may be required. Visual monitoring for gas bubbles in the canal in 2012-2013 indicated an absence such that significant gas ebullition is not anticipated. A typical geomembrane product for this application would be 40 mil thick high density polyethylene (HDPE). This material is very strong and tough, and would provide an effective barrier to shallow root penetration, which is typically no more than about 1 foot for black, white, and button mangrove species. Further, the roots of black, white, and button mangroves are not only shallow but also lack the strength and firmness required to penetrate a 40 mil HDPE plastic liner. Because of the impermeability and wide acceptance of plastic membrane barriers, this option is carried further for consideration at the site.

AquaBlok, when properly placed provides an impervious layer that slows or prevents the flow of pore water into the surface water column. This material can also be used in conjunction with reactive materials such as organophilic clay to direct pore water flow through a treatment material ("funnel and gate"). Because AquaBlok is applied as a granular material and becomes a soft matrix, it adds little or no strength to the soft sediment containment system. If combined with a geotextile AquaBlock's function would be enhanced, but like the organophilic clay material, successful application in the shallow water of the upper canal was not tested in the field pilot study and would be problematic because of issues with floating equipment access, and difficulties with application and verification. Also, concerns that mangrove roots or gas accumulation could penetrate the soft AquaBlok matrix and create a path for constituent migration reduce the reliability of this technology. Thus, the AquaBlok option is not considered further.

4.1.5 Erosion Control

This includes large gravel and stone to protect the cap or fill material from currents and, possibly, waves, and also to protect drainage swales in the fill option from stormwater erosion. Installation is typically made by dropping through the water column or placing directly on the swale bottom and banks. Actual size of stone and thickness of layer(s) will be determined during design. Locally available 6- to 8-inch stone is assumed for costing purposes.

4.1.6 Vertical Containment

The thick unconfined layer of soft sediment in the upper canal could migrate under the weight of fill/cap and erosion control materials. To prevent migration, a vertical barrier would be placed in the canal at the downstream end of the fill/cap (vehicle bridge). This barrier would consist of a steel sheet pile wall driven across the canal down to the top of rock or refusal. The sheets would be interlocked to provide a continuous wall, and the top would be at or just above the top layer of the fill/cap.

4.1.7 In Situ Treatment

Innovative treatment technologies such as in situ treatment of subsurface sediments is an emerging technology being investigated by researchers for effectiveness and practicality. Most demonstrations have been lab scale or field scale pilot tests. Typically, these technologies involve injection of amendments to sequester dissolved and/or free product constituents. The injection, mixing, and capacity of these amendments to immobilize these dissolved and free product constituents are ongoing challenges being addressed by research. Because of the high PAH concentrations and occurrence of free product (dripolene) in the upper canal sediments, in situ injection of materials into subsurface sediment is not considered a viable option at this time.

4.1.8 Sediment Removal, Dewatering, Treatment, and Disposal

A special evaluation was performed for technologies consisting of excavating impacted sediment to prescribed depth(s), dewatering excavated sediment, sediment solidification or thermal treatment, disposing of dewatered sediment, and backfilling the excavation. Evaluation of these technologies follows.

- Hydraulic dredging requires a large confined disposal area to accept the slurry and allow solids to settle out. Dewatering of the settled solids is required, which may require additives/amendments (i.e. Portland Cement or other pozzolans, polymers, etc.) large mechanical dewatering equipment, or long drying times. Because of these challenges, hydraulic dredging is not considered feasible for this site.
- Mechanical dredging would be performed by a long reach backhoe (excavator) operating from the bank and disposing into roll-off containers or a contained treatment area on the banks for dewatering. Bank access is problematic without disturbing mangroves. Alternately, excavating from a barge and transporting the sediment to shore is feasible, but would be more time consuming and require double handling of the impacted material. This technology is applicable more to spot removal of contaminants which is not required to achieve the sediment remedial goals .
- Dewatering would be attempted by gravity drainage first; if required, drying agents such as pozzolan or polymers would be added and mechanically mixed to speed drying.
- Onsite disposal is not an option, as there are no available disposal units onsite for K022 listed waste. Offsite disposal is limited to hazardous waste disposal facilities in the U.S. (there are none in Puerto Rico), requiring shipment by sea.

Based on a brief evaluation of the offsite disposal option, any remedy requiring a significant amount of offsite disposal would be prohibitively expensive. Off-island disposal would require highway transport (dewatered sediment) to a Puerto Rico port, ocean transport to U.S. port, highway transport to a U.S. disposal facility (Deer Park, Texas), and tipping fees for landfill disposal. Treatment would be required at the disposal facility prior to landfilling for sediments not meeting land disposal restrictions. These costs alone (not including excavation and dewatering at the site) would exceed $25 million for the first 2 feet of sediment throughout the canal. To remove all contaminated sediment from the canal, the treatment and disposal costs would exceed $100 million. Similarly, the estimated cost for an option including sediment removal, onsite thermal treatment, and return of treated sediment to the canal is estimated to exceed $15 million not including fuel, excavation, dewatering, and site controls.

In addition, mechanical dredging of large volumes of impacted sediments (some containing pockets of free dripolene), dewatering it, and transporting the dewatered sediment over highways and the Caribbean Sea and Gulf of Mexico to the U.S. mainland presents many risks of uncontrolled releases of the impacted sediment and water from dewatering operations. As indicated previously, the costs presented exclude excavation and dewatering of the sediment, as well as stabilization/solidification of the sediment to meet marine transport standards (to prevent liquefaction of the sediment during transport).

To summarize the cost evaluations:

- The estimated cost for treatment (ex situ), transportation and disposal of the top 2 feet of sediment using a disposal facility in the U.S. mainland exceeds $25 million, while this estimated cost for all of the sediment exceeds $100 million. These costs do not include dredging and dewatering.
- On site thermal treatment (ex situ) of all contaminated sediment and return of treated sediment to the canal was estimated to exceed $15 million. This does not include dredging and dewatering.

In conclusion, removal, treatment, and disposal technologies are considered impracticable and are not further evaluated. This CMS addresses the use of engineering controls, such as containment, for contaminated media, which can be reliably implemented and will pose relatively low long-term risk.

To supplement the engineering controls, institutional controls may be continued/implemented to restrict access and intrusive activities. Institutional controls would likely include a deed restriction prohibiting certain activities that could potentially damage or otherwise render the corrective action ineffective for controlling risks associated with the isolated/contained sediment. Such deed restrictions would follow the ownership of the property whereby the owner would be responsible for complying with the deed restrictions.

4.1.9 Technology Evaluation Summary

Based on this technology evaluation, the screening of these technology options is summarized in Table 4-1. This table presents the technology screening processes, and summarizes the general viability and effectiveness of each technology option as it relates to the site, constituents, and other identified technologies. The most effective, proven, and viable technologies are retained for further consideration in the development of remedial alternatives. Given the limitations and challenges of treatment technologies for the canal sediment constituents, the remedial focus is on source control remedies (containment options).

Where multiple, distinct technology options are identified with similar attributes, detailed evaluation of each of the options would be lengthy and complex, likely with little clear overall performance advantage of any one option. Thus, a representative option was identified and selected to represent the group of similar options. The nonselected but similar options were removed from further evaluation; however, these nonselected options may be viable and could be further evaluated in subsequent design phases if found to be advantageous to the selected remedy. For example, a 40-mil thick high-density polyethylene (HDPE) geomembrane is selected for detailed evaluation, but other similar options that could also be advantageous include linear low-density polyethylene (LLDPE) geomembrane and geocomposite clay liner (GCL). The representative technology options retained for development of candidate alternatives are listed in Table 4-2.

TABLE 4-1
Screening of Sediment Technologies
SWMU 5 CMS, PTPLLC, Peñuelas, Puerto Rico

Technology/Option	Advantages	Limitations	Conclusion
Fill	Provides significant physical barrier; no further constituent exposure in upper canal. Relatively simple to implement.	Requires moderate quantity of material; disturbs existing marine ecosystem. Special placement process required on soft sediment.	Best limited to shallow areas where cap may not apply. Was tested in treatability study. Viable for upper canal.
Fill with Onsite Materials	Use of onsite material is efficient, less traffic, lower carbon footprint.	Material classification highly variable; disturbs existing marine ecosystem; some may be too fine grained; borrow operation would require permitting.	Possible cost advantage depending on availability and cost of offsite materials; however, long and expensive permit process required and material suitability concerns. Not further evaluated.
Fill with Offsite Materials	Good control of material properties; large volumes available commercially.	Delivery of large volumes could be problematic based on previous project experience. Disturbs existing marine ecosystem.	Possible advantage to avoid permitting issues and material variability compared to onsite material. Was tested in treatability study. Viable for upper canal.
Geotextile Mat	Effective as support layer for cap or fill on soft sediments; readily available based on other projects.	Placement in canal would require special equipment and skilled installers. Disturbs existing marine ecosystem;	Would be effective as support for fill, erosion protection, or cap layers. Viable with appropriate installer.
Active Capping	Very effective for sequestration of sediment and pore water organic constituents. Can be placed via mats, bulk, or coated aggregate; can be combined with low permeability materials.	Capacity for constituent sequestration is high, but has a definite limit; may require sand cover for physical and benthic barriers, and armoring to protect from erosion; disturbs existing marine ecosystem. Would be difficult to install from the banks in the upper canal due to small thickness tolerances and verification challenges.	Was not tested in the treatability study in the upper canal. Would be difficult and expensive to apply and verify. Not further evaluated.
Passive Capping with Pervious Material	Sand caps are common and provide confinement of other cap layers and physical separation for benthic organisms. Fine-grained pervious materials reduce permeability and increase adsorption.	Sand capacity for constituent sequestration is low, and constituents could migrate through cap over time; may require armoring to protect from erosion; disturbs existing marine ecosystem. Fine-grained materials are more difficult to install and stabilize.	Would not be as effective as reactive media in sequestering organic constituents, and constituents could break through over time. Would be a good physical barrier over reactive materials or membrane. Fine-grained materials are beneficial if successfully placed. Sand was tested in treatability study. Sand may be used as general fill.
Passive Capping with Impervious Material	Clay or membrane cap prevents constituent flux from sediment and pore water into the	Clay application through the water column involves a proprietary material (AquaBlok); it was tested in the treatability study in the lower canal, but would be	AquaBlok could be an effective containment component but has reliability concerns and would be more difficult and expensive to

TABLE 4-1
Screening of Sediment Technologies
SWMU 5 CMS, PTPLLC, Peñuelas, Puerto Rico

Technology/Option	Advantages	Limitations	Conclusion
	surface water. Not very susceptible to gas ebullition disturbances.	difficult to install from the banks in the upper canal due to small thickness tolerances and verification challenges. Disturbs existing marine ecosystem. Membranes may be challenging to install under water; but skills are available, and most of the installation can be done from the banks. Both options would require a benthic cover layer and/or armor.	install and verify. The membrane option is viable and could be installed in the upper canal from the banks.
Dredging (Mechanical)	Removes constituents from the dredged area. Technology is established and available.	Constituent migration possible because of suspended sediment during dredging; controlled by BMPs; disturbs existing marine ecosystem. Excavated material must be disposed of.	Useful to remove pockets of highest concentrations, but these are not part of the cleanup goals based on the findings of the benthic invertebrate study. Environmental clamshell and BMPs would reduce suspended sediments. Not applicable because there are no appropriate disposal options (see Disposal), so not further evaluated.
Dredging (Hydraulic)	Removes constituents from the dredged area. Technology is established and available.	Constituent migration likely caused by suspended sediment during dredging; controlled by BMPs; disturbs existing marine ecosystem. Large volumes of water with excavated material must be disposed of in cells and treated.	Large volume of water must be treated before discharge to canal; no viable disposal options for solids (see Disposal). Not applicable because of these difficulties and high costs, so not further evaluated.
Disposal	Wastes are contained in onsite or offsite permitted, monitored disposal facility.	Disposal area requires perpetual care, monitoring and regulation. May require treatment before disposal to meet landfill disposal restriction.	No onsite or offsite treatment, storage, and disposal facilities in Puerto Rico. Would require transport to U.S. at significant risk and cost. Not applicable because of these difficulties and high costs, so not carried forward.
Erosion Control	Stone protects cap layers and fill from erosion damage. Stone size and layer thickness can be sized according to currents and waves.	Stone adds weight to underlying sediments. May disturbs existing marine ecosystem. Usually requires a geotextile bedding.	Common stone sizes are applicable and will be used for study; final sizing during design.
Vertical Containment	Structural sheet pile wall is a reliable technology to prevent lateral migration of contaminated sediment.	Large floating equipment may be required. Some underwater (diver) work may be required.	Viable with appropriate installer. Will be included with fill/cap options to provide vertical containment.

TABLE 4-1
Screening of Sediment Technologies
SWMU 5 CMS, PTPLLC, Peñuelas, Puerto Rico

Technology/Option	Advantages	Limitations	Conclusion
In Situ Treatment	If effective, could reduce toxicity, mobility, or volume (TMV) of impacted sediment. Injection of reactive media currently being tested by others.	Effective, reliable treatment for PAHs has not been demonstrated at full scale.	Not currently viable at field scale for PAHs.
Ex Situ Treatment	If effective, could reduce toxicity, mobility, or volume (TMV) of impacted sediment. Stabilization would reduce the mobility of PAHs and low temperature thermal desorption would reduce the concentration of PAHs in the sediment.	Treatment is difficult and expensive, and requires large volumes of water to be treated. Treatment and disposal cost of all contaminated sediment would exceed $100 million. Treatment and transportation of the waste raises potential for uncontrolled releases.	Cost of treatment and disposal relative to other technologies/options is impractical. Handling, treatment, and transportation (over land and sea) of large volumes of waste increases risk of uncontrolled release of hazardous constituents. Not applicable because of these difficulties and high costs, so not carried forward.

TABLE 4-2
Applicable Technologies for Remedial Alternatives [a]
SWMU 5 CMS, PTPLLC, Peñuelas, Puerto Rico

Technology	Comments
Fill with Offsite Materials	Sand and caliche are effective for CWC fill; large volumes may be required. Placement below water in canal requires specialized skill and equipment.
Geotextile Mat	Effective for improving sediment stability. Placement underwater requires special equipment. Typically required under erosion protection stone.
Geomembrane	Effective barrier over contaminated sediment in upper canal. Placement requires special equipment/procedures.
Erosion Control	Large gravel to fist size stone or larger rock is effective in protecting fill and swale surfaces from storm water erosion.
Vertical Containment	Effective in containing fill at the downstream end. Placement requires specialized skill and equipment.

[a] Applicable technology is both viable and effective.

4.2 Remedial Alternatives Development

The remedial technology evaluation results in a list of viable technologies that can be combined in different ways to develop candidate alternatives for corrective measures. In addition to the No Action alternative, the following two alternatives were developed from the viable technologies included in Table 4-2 to address both the upper and lower canal sections:

Fill over a plastic membrane/cap in the upper canal to contain sediments in place, preventing exposure of benthic organisms to underlying sediment, and eliminating subaqueous substrate for a future benthic community to develop in the northern, upland end, but supporting new benthic community development at the southern end within the tidally influenced portion of the swale. No action will be performed in the lower canal.

- Fill over a plastic membrane/cap in the upper canal to contain sediments in place, preventing exposure of benthic organisms to underlying sediment, and eliminating subaqueous substrate for a future benthic community to develop in the northern, upland end, but supporting new benthic community development at the southern end within the tidally influenced portion of the swale. Perform long-term monitoring of the lower canal.

The development and detailed descriptions of the candidate alternatives for this study are presented in this section.

4.2.1 Alternative 1: No Action

Alternative 1 is the No Action alternative, for which no remedial activities would be performed. This includes no monitoring and no further institutional or engineering controls. The site would essentially be abandoned.

This alternative does not meet requirements for many of the screening criteria as shown in Table 4-1; benthic organisms in the upper canal sediments would be exposed to high concentrations of PAHs and dripolene product; these sediments would be susceptible to migration caused by erosion during major storm events.

There is no cost or time to completion associated with this alternative.

4.2.2 Alternative 2: Cap and Vertical Barrier for the Upper Canal

Alternative 2 includes placing a cap on the upper canal bottom to cover sediment from the north end down to the vehicle bridge, where a vertical sheet pile wall would be constructed across the canal to contain the cap and sediment. Downstream of the wall, the canal would not be affected. Alternative 2 is shown in profile in Figure 4-1.

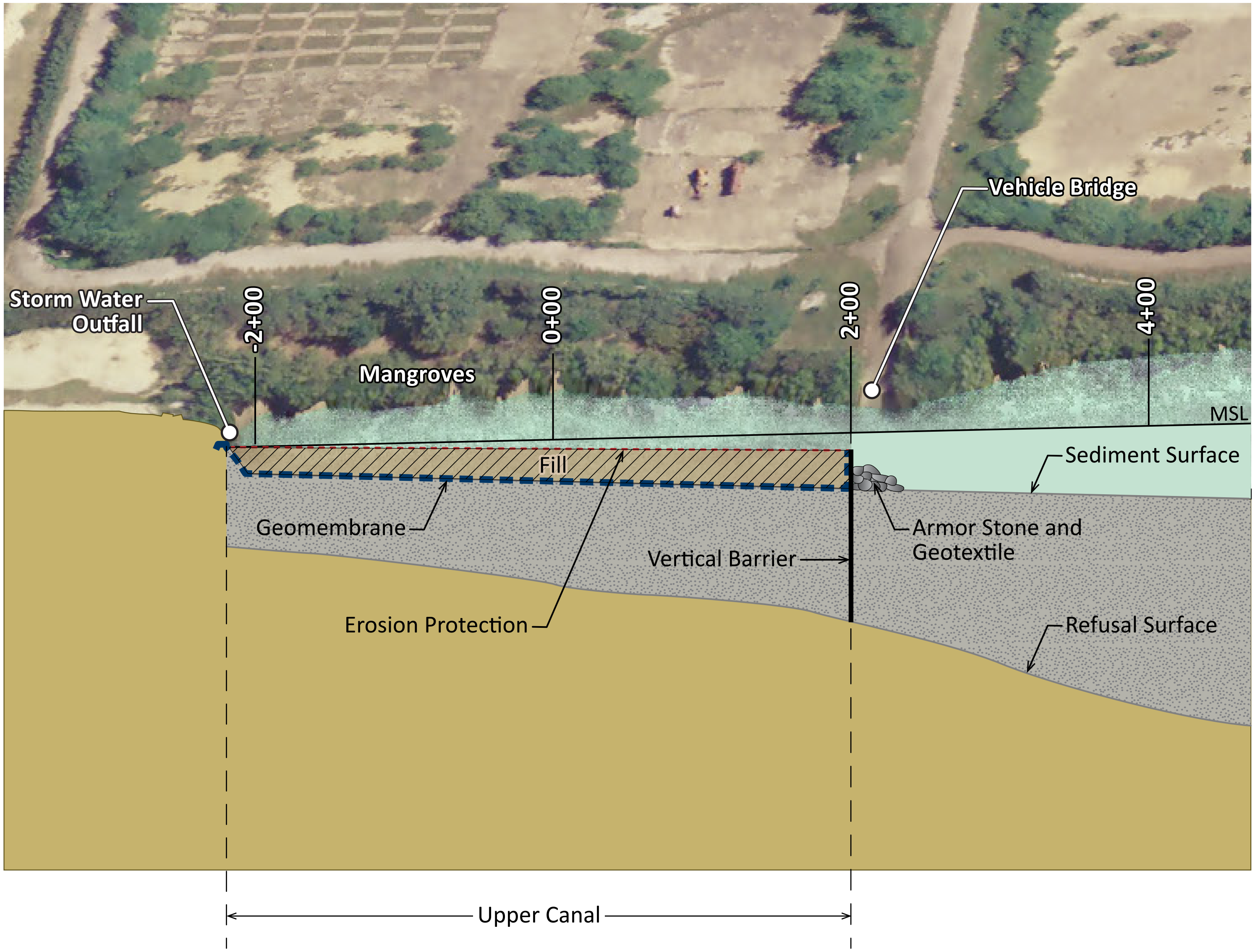

FIGURE 4-1
Profile: Alternatives 2 and 3
SWMU No. 5 CMS Report
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The cap would consist of a geomembrane placed directly on the sediments, and fill to a thickness appropriate to support mangrove establishment and drainage. Upstream of approximate Station 2+00 (vehicle bridge), the cap would be placed between the water lines of the canal banks (see Figure 4-2). Erosion control and a drainage swale would be provided to protect the cap and pass the drainage from upstream. Because of the shallow depths in this section, the swale elevation would be higher than tidal influences toward the upper (north) end of the canal and toward the side banks, but the swale near the vehicle bridge would be under water. Portions of the mangroves along the banks would be removed to anchor the geotextile and allow fill placement. New mangroves, including white, button, and black mangroves, would be propagated throughout the swale area, banks, and other disturbed areas so that there would be no net loss of mangrove area.

Cap Material

The cap would consist of a 40-mil HDPE geomembrane with heat-welded field seams to provide separation and support for the fill and an impermeable cover. Offsite material such as caliche, sand, topsoil, or mixed soil will be added above the geomembrane to cover the geomembrane material and to support growth of mangroves and benthic habitat. Fill material will be placed by conventional construction equipment (bulldozer, loader, excavator) or by specialized machinery in thin horizontal lifts. The thickness of the lifts will be controlled primarily to limit unbalanced loads on the sediment. Some consolidation of the underlying sediment is expected during and after fill placement. Initial estimates based on consolidation testing during the Phase 1 Treatability Study (see Appendix A) indicate potential consolidation settlements of up to 0.4 foot for each foot of fill. This projected settlement volume is included in the total volume of fill estimated.

Vertical Wall

A sheet pile wall will be constructed at approximately Station 2+00 so that the top of the wall will be just above the top of the cap, but below the average water level at low tide.

Erosion Protection

Armor stone will be placed in the swale within the fill/capped area to protect the fill from stormwater erosion. This stone and the stone placed at the downstream vertical barrier will be designed to protect against tidal currents and waves associated with hurricanes and extreme rain events.

Mangroves

The banks will require mangrove removal to anchor the geomembrane and allow placement of fill. New mangroves will be propagated along the banks of the new swale to replace those removed. Other disturbed areas will be allowed to propagate naturally with mangroves and other plants at the site.

Operation and Maintenance

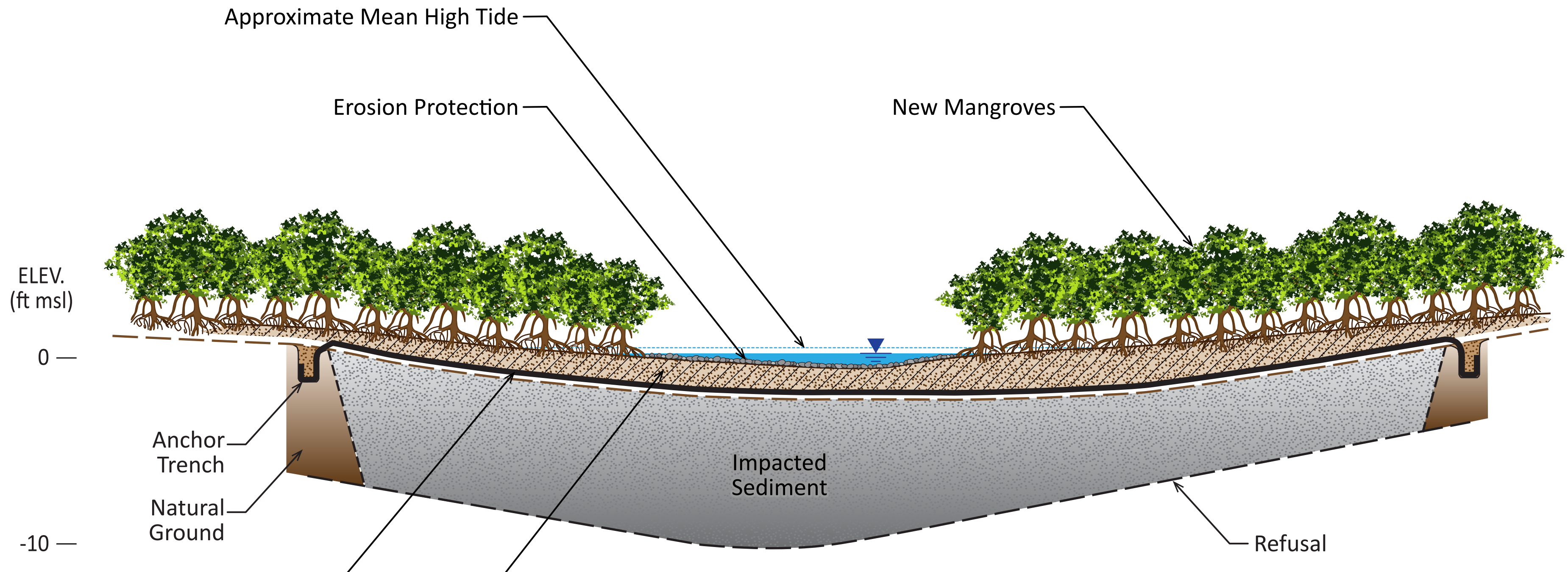
None of the technologies considered for remediation would require operation, but some maintenance would be required on the cap. It is expected that annual inspections would be performed to check the effectiveness of the containment components (cap and sheet pile, vegetation, erosion control). This would include visual inspections for damage caused by storms and repairs of such damage. A brief report would be produced for each inspection presenting observations, any problems noted, and recommended repairs/maintenance.

To supplement these engineering controls, existing site and institutional controls would be continued/implemented to restrict access and intrusive activities. These include fencing, security, work permitting, and use and zoning restrictions. The owner is expected to retain title to the remediated lands to enforce and maintain controls.

Best Management Practices

BMPs will be used to monitor and control the following:

- Mangroves - minimize damage to mangroves that are not displaced by construction
- Sediment displacement - minimize disturbance to and displacement of impacted sediment during remedial work



STA 2+00
Section

FIGURE 4-2
Section: Alternatives 2 and 3
SWMU No. 5 CMS Report
PTPLLC, Peñuelas, Puerto Rico

CH2MHILL

- Resuspension of solids – minimize migration of suspended solids to downstream portions of the lower canal
- Erosion control – prevent erosion of solids during and after construction

No cap or erosion protection is required in the lower canal; current and wave erosive forces are mitigated by the depth of water and mangrove density.

Institutional Controls

PTPLLC proposes to establish a deed restriction that will require the implementation of access controls to prohibit intrusive activities that would damage the cap and vertical wall in the northern portion of the canal, and potentially disturb the sediments in the lower canal. This would include the existing fencing and security service, as well as the installation of warning signs along the canal and near the mouth of the canal to prevent unauthorized personnel from entering the canal. The deed restriction will be filed with the Puerto Rico Property Registry so that the deed restriction would follow the land and apply to future land owners.

4.2.3 Alternative 3: Cap and Vertical Barrier for the Upper Canal and Long-Term Monitoring of the Lower Canal

Alternative 3 is identical to Alternative 2 for the upper canal. Alternative 3 adds long-term monitoring of the lower canal surface sediment and benthic communities.

Long-term monitoring would be performed to confirm the continued stability of the benthic community in the lower canal. This monitoring would be in addition to the periodic inspections and reviews of the upper canal cap, and would include benthic infauna sampling and analysis in years 5, 15, and 25 after implementation of the remedy. Each monitoring event would consist of the following:

- Benthic community and co-located sediment chemistry will be sampled for surface sediment (0 to 0.5 foot) at six native and two background stations. Native stations would be located at T-4, -6, -8, -10, -12, and 14 and background stations would be BKG-1 and BKG-2 as shown in the Benthic Study Report (CH2MHILL 2014).
- Benthic samples will include three replicates at each station;
  8 stations x 3 replicates = 24 samples per event (plus quality control [QC] samples).
- Sediment chemistry analyses will include PAHs, TOC, and particle size;
  one sample per station = 8 samples per event (plus QC samples).
- Field water quality measurements will be made at each station during each event, including dissolved oxygen, temperature, pH, salinity, conductivity, and turbidity.
- Summary report will be presented and include procedures, results, comparisons to results of previous events, and conclusions on the stability of the benthic community.

4.3 Remedial Alternatives Screening

The USEPA (2003) prescribes a two-phased evaluation for remedy selection. During the first phase, potential remedies are screened to determine if they meet four performance standards. The performance standards are considered the main goal of the cleanup and all remedial and corrective measure alternatives must meet the performance standards. Remedies that meet these standards are then evaluated in the second phase using five balancing criteria to identify the remedy that provides the best relative combination of attributes. Other factors may be evaluated as well. The three alternatives and their meeting of performance criteria are presented in the first part of Table 4-3 as follows.

- Protect human health and the environment. How engineering controls (physical barriers for containment) and institutional controls (restricted land use activities) protect ecological receptors from contact with hazardous constituents in the sediment.

- Attain applicable media cleanup goals (provided in Section 3.2). Will non-numerical cleanup goals be met by isolating contaminated sediments to minimize or block the contact of ecological receptors with impacted sediments in the upper portion of the canal, and to prohibit activities that could result in future migration of subsurface contaminated sediment in the lower portion of the canal to surface sediments or other water bodies?
- Reduce or eliminate further releases of hazardous wastes and constituents that may pose a threat to human health and the environment. Will the physical barriers and institutional controls contain and prevent further releases of constituents from the sediment to the canal environment.
- Comply with applicable waste management standards. During implementation will activities, decontamination liquids and protective clothing be contained and managed in accordance with the facility permit, and be removed from the site by licensed commercial waste disposal specialists.

The balancing criteria are also included and assessed in Table 4-3. These balancing criteria are the key factors in selecting the recommended remedy (see Section 4-4).

4.4 Comparative Analysis of Alternatives

The alternatives comparison in Table 4-3 indicates Alternative 1 does not meet performance criteria, but both remedial Alternatives 2 and 3 meet the four performance criteria, including the non-numerical cleanup goals. The selection of the preferred remedy is therefore based on the evaluation of the relative merits of Alternatives 2 and 3 using the balancing criteria and other factors described in this section.

4.4.1 Balancing Criteria Evaluation

Comparative analyses between Alternatives 2 and 3 for each of the balancing criteria were performed and are presented in the following sections to highlight the relative advantages and disadvantages.

Long-term Reliability and Effectiveness

The long-term reliability and effectiveness of Alternatives 2 and 3 are identical in the upper canal. In the lower canal, Alternative 3 improves reliability somewhat because of the periodic sampling and testing to confirm continued benthic stability. There are no data to suggest any instability of the benthic community exists, however, and periodic O&M inspections would provide adequate long-term observations of both upper and lower canal conditions. Institutional controls would prevent future disturbance to the canal such as excavation or other potential exposures.

Reduction in the Toxicity, Mobility, or Volume of Wastes

The reduction in constituent mobility of Alternatives 2 and 3 is identical.

Short-term Effectiveness

Risks to workers or to the environment during implementation of Alternatives 2 and 3 is identical.

Implementability

The implementability (permitting, time of construction, and availability of materials and services) of Alternatives 2 and 3 is identical in the upper canal. In the lower canal, implementation of the remedy in the form of periodic sampling and testing will continue for up to 25 years. Given the historical stability of the marine habitat of the lower canal, it is unlikely to be disturbed in the future. The O&M inspections would provide adequate long-term observations of both upper and lower canal conditions.

Cost

Alternatives 2 and 3 are similar in capital cost; Alternative 3 has a higher total cost because of the periodic sampling and testing of benthic organisms in the lower canal over time.

4.4.2 Summary Evaluation

Alternative 1, No Action, is not protective of benthic organisms in the upper canal and the potential for migration of constituents in the upper canal is not addressed; therefore, No Action is not an acceptable remedy.

Alternatives 2 and 3 both provide an effective, long-term cap and vertical barrier in the upper canal to contain impacted sediments, including dripolene product, and provide a new aquatic/wetland habitat above the sediment. This new habitat will support benthic and other organisms, and restore mangroves throughout the upper canal area. Erosion control will maintain and prevent storm damage to the cap. Both alternatives recognize the observed diverse benthic community in the lower canal surface sediments and the lack of any need for remediation. Alternative 3 does also provide for periodic sampling and testing of the sediment and benthic community in the lower canal to confirm the stability of the conditions over time.

A large number of samples and tests were conducted throughout the lower canal and background stations during the benthic study and a large amount of data were generated, evaluated, and reported in the Benthic Study Report (CH2M HILL 2014). There is very little uncertainty in the benthic community health in the lower canal and additional studies in the future are unlikely to indicate any significant variations; therefore, the additional monitoring is not considered necessary and Alternative 2 is the recommended remedy.

TABLE 4-3
Screening of Remedial Alternatives
CMS Report, PTPLLC, Peñuelas, Puerto Rico

Evaluation Criteria	Alternative 1: No Action	Alternative 2: Cap and Vertical Barrier for the Upper Canal	Alternative 3: Cap and Vertical Barrier for the Upper Canal and Long-Term Monitoring of the Lower Canal
1. Protect Human Health and the Environment	Alternative 1 is protective of the environment for the lower canal, but not for the upper canal, where sediment constituents are not contained and benthic exposure is not prevented.	Alternative 2 is protective of the environment via a cap (membrane and fill material) over sediment in the upper canal; this isolates the constituents from benthic organisms. A vertical barrier prevents movement of contaminated sediment and cap material downstream of the remedy. The lower canal supports a diverse benthic community. No current risk to human health, so protection not required. Potential for unacceptable future human health risks with change in land use would be addressed through administrative restrictions.	Alternative 3 is protective of the environment via a cap (membrane and fill material) over sediment in the upper canal; this isolates the constituents from benthic organisms. A vertical barrier prevents movement of contaminated sediment and cap material downstream of the remedy. The lower canal supports a diverse benthic community that is confirmed by periodic testing. No current risk to human health, so protection not required. Potential for unacceptable future human health risks with change in land use would be addressed through administrative restrictions.
2. Attain Media Cleanup Goals	This alternative does not comply with media cleanup goals because sediments with elevated PAH concentrations in the upper portion of the canal are not isolated from benthic organisms.	This alternative complies with media cleanup goals by isolating sediments in the upper portion of the canal that contain elevated PAH concentrations that may adversely impact ecological receptors with a protective cap. The benthic community throughout the remainder of the canal has been documented as unimpaired. Non-numerical media cleanup goals will be met at the completion of corrective action construction.	This alternative complies with media cleanup goals by isolating sediments in the upper portion of the canal that contain elevated PAH concentrations that may adversely impact ecological receptors with a protective cap. The benthic community throughout the remainder of the canal has been documented as unimpaired. Non-numerical media goals will be met at the completion of corrective action construction.
3. Control the Sources of Releases	Alternative 1 does not control releases of PAH constituents in the upper canal. Migration of contaminated sediment into the marine environment is not prevented, especially during major storm events.	Alternative 2 controls releases of PAH constituents and prevents benthic contact with contaminated sediment in the upper canal by providing a cap that isolates the constituents with a protective physical barrier. No barrier is required in the lower canal. Institutional controls will address protection of lower canal subsurface sediments from disturbance activities.	Alternative 3 controls releases of PAH constituents and prevents benthic contact with contaminated sediment in the upper canal by providing a cap that isolates the constituents with a protective physical barrier. In the lower canal, no barrier is required and benthic health is confirmed periodically by sampling and testing. Institutional controls will address protection of lower canal subsurface sediments from disturbance activities.
4. Comply with Applicable Standards to Manage Wastes	No wastes will be managed	Other than being covered by a membrane and fill cap, no wastes will be managed. Waste from construction activities such as PPE and decontamination fluids/residues will be disposed of offsite by a licensed hazardous waste contractor. Implementation will comply with applicable permits.	Other than being covered by a membrane and fill cap, no wastes will be managed. Waste from construction activities such as PPE and decontamination fluids/residues, and from periodic sampling activities of sediment in the lower canal, will be disposed of offsite by a licensed hazardous waste contractor. Implementation will comply with applicable permits.
5. Comply with the following other factors:			
(a) Long-Term Reliability and Effectiveness	No isolation is provided between the contaminated sediment and receptors in the upper canal. No reliable containment or protection from erosion. Residual exposure risk to future industrial workers.	The membrane and fill cap provide positive isolation between the contaminated sediment and receptors in the upper canal. Fill and cap materials are stable and reliable containment for performance life of 30 years or more. Sediment and cap material in the upper canal are contained by a vertical barrier to prevent movement downstream. Concentrations of PAHs exceeding media cleanup standards would remain immobilized below the cap. Rip rap or armor stone would protect cap fill from erosion. Requires minimal operations and maintenance (O&M). Benthic organisms in the lower canal are thriving and show no signs of impacts from sediment constituents. Because of the depth of water, deeper (below benthic zone) constituents are not subject to wave and current erosion. Administrative restrictions are expected to be effective in minimizing residual risk by preventing disturbance, erosion, and worker exposure to wastes during future industrial use.	The membrane and fill cap positive isolation between the contaminated sediment and receptors in the upper canal. Fill and cap materials are stable and reliable containment for performance life of 30 years or more. Sediment and cap material in the upper canal are contained by a vertical barrier to prevent movement downstream. Concentrations of PAHs exceeding media cleanup standards would remain immobilized below the cap. Rip rap or armor stone would protect cap fill from erosion. Requires minimal O&M. Benthic organisms in the lower canal are thriving and show no signs of impacts from sediment constituents. Because of the depth of water, deeper (below benthic zone) constituents are not subject to wave and current erosion. Success of remedy is monitored by periodic benthic community and chemical sampling and testing. Administrative restrictions are expected to be effective in minimizing residual risk by preventing disturbance, erosion, and worker exposure to wastes during future industrial use.
(b) Reduction of Toxicity, Mobility, or Volume of Wastes	No reduction of TMV.	Sediments are not treated, but mobility of PAH constituents are significantly reduced in the upper canal.	Sediments are not treated, but mobility of PAH constituents are significantly reduced in the upper canal.
(c) Short-Term Effectiveness	No construction, thus no risks to workers or community caused by construction.	Area is industrial with no nearby residents. Risks to community during construction include material truck deliveries. These risks would be minimized through implementation of a construction health and safety plan. Employing appropriate health and safety procedures and protective equipment will minimize risks to workers from exposure to constituents. Migration of disturbed sediment during construction would be controlled with BMPs such as turbidity controls.	Area is industrial with no nearby residents. Risks to community during construction include material truck deliveries. These risks would be minimized through implementation of a construction health and safety plan. Employing appropriate health and safety procedures and protective equipment will minimize risks to workers from exposure to constituents. Migration of disturbed sediment during construction would be controlled with BMPs such as turbidity controls.

TABLE 4-3
Screening of Remedial Alternatives
CMS Report, PTPLLC, Peñuelas, Puerto Rico

	Evaluation Criteria		**Alternative 1: No Action**	**Alternative 2: Cap and Vertical Barrier for the Upper Canal**	**Alternative 3: Cap and Vertical Barrier for the Upper Canal and Long-Term Monitoring of the Lower Canal**
(d)	Implementability	No implementation issues.		Clean Water Act and dredge and fill permits may be required prior to placing cap and sheet pile wall. Application preparation and agency approval can take a year or more. Corrective action construction would likely take 4 to 6 months to implement after permitting and design. The capping technology and deployment equipment require specialized worker skills and equipment. Sheet pile technology and deployment equipment are proven and readily available in Puerto Rico. Filling was tested in the treatability study.	Clean Water Act and dredge and fill permits may be required approved prior to placing cap and sheet pile wall. Application preparation and agency approval can take a year or more. Corrective action construction would likely take 4 to 6 months to implement after permitting and design. The capping technology and deployment equipment require specialized worker skills and equipment. Sheet pile technology and deployment equipment are proven and readily available in Puerto Rico. Filling was tested in the treatability study.
(e)	Cost	**Capital**	$0	$2,168,000	$2,178,000
	(2014 Dollars)	**Annual O&M**	$0	$20,000	$26,000
		Present Worth	$0	$2,337,000	$2,397,000

This is a DRAFT Rough-Order Cost estimate. Remedy scope assumptions used to estimate these costs are presented in Appendix D.
The information in this cost estimate is based on the best available information regarding the anticipated scope of the remedial alternatives. Changes in the cost elements are likely to occur as a result of new information and data collected during the engineering design of the remedial alternatives. **This is an order-of-magnitude cost estimate that is expected to be within -30 to +50 percent of the actual project costs**.

Present worth estimates are based on an effective interest rate of 10 percent per year for an O&M period of 30 years.

Description of Recommended Corrective Measure Alternative

5.1 Alternative Description

The recommended Alternative 2 consists of the following remedial components:

- Site controls and preparation, including stormwater management, turbidity controls, staging areas, and material sources.
- Mangrove removal from the active remedy area for access and installation of cap materials. Estimated area to be cleared is 0.5 acre based on a 20-foot wide construction zone along the banks of the upper canal and a 50-foot by 50-foot access way.
- Mangrove root and branch decontamination/disposal may be required depending on contact with impacted sediment and ability to leave portions of the mangroves in place. These issues will be addressed during remedy design based on further characterization of the canal topography and mangrove removal processes. For this CMS, the following assumptions were made:
  - Mangrove roots and branches in contact with impacted sediment will be left in place to the extent possible to allow geomembrane placement.
  - Mangrove roots and branches that must be removed and do not have dripolene on the plants will be rinsed to remove solids and left onsite.
  - Mangrove roots and branches that must be removed and have dripolene on them will be cut into pieces, place in sealed containers, and disposed of offsite. A total of two 10-cubic-yard (yd^3) rolloffs (20 yd^3) are assumed for disposal.
- A permanent sheet pile wall installed across the canal at the vehicle bridge from bank to bank. Estimated sheet pile parameters: 80 feet long bank to bank and average depth of 12 feet (960 square feet [ft^2]).
- An estimated 52,800 ft^2 of 40 mil HDPE geomembrane placed directly on the sediment of the upper canal followed by a layer of fill from 2 to 4 feet thick (estimated total in place volume, including additional fill caused by settlement, is 4,066 yd^3). Consolidation settlement does not occur all at once. Fill will be placed in thin lifts to facilitate controlled settlement; phased placement may be required to reach final grade. Approximately 2,066 yd^3 of the fill will be caliche and 2,000 yd^3 will be topsoil. Geomembrane will cover bank to bank, from downstream sheet pile wall to upstream end of canal. Contouring of the fill will be performed to provide appropriate upland, wetland and aquatic habitats, drainage, erosion control, and cover of the membrane.
- Erosion control consisting of geotextile and armor stone in the swale within the filled/capped area and other erodible areas. Estimated erosion control parameters: 8,800 ft^2 of geotextile and 300 yd^3 of stone in the upper canal and 500 ft^2 of geotextile and 74 yd^3 of armor stone at the vertical wall.
- Mangrove propagation in the wetland and aquatic habitats formed by the new cover and in other disturbed areas; this includes follow-up inspection and restoration for permanent mangrove establishment. Inspections will confirm both the success of the propagation of the mangroves and the membrane resistance to root penetration. The estimated 0.5 acre of mangroves that will be cleared for construction plus an additional 0.3 acre of the cap area will be restored with mangroves and other

wetland vegetation (total 0.8 acre). The remaining 0.7 acre of the total project area will include surface water, erosion protection, and natural vegetation areas.

- Periodic inspection and reporting to confirm performance and stability of these components.
- Site maintenance and institutional controls: fencing, security, and deed restrictions which would prohibit activities that could compromise the integrity of the containment/cap system that would apply to existing and future property owners.

The components and sequence of the recommended Alternative 2 are presented in Figures 5-1 (profile), 5-2 (sections), and 5-3 (detailed section).

5.2 Protect Human Health and the Environment

Alternative 2, Cap and Vertical Barrier for the Upper Canal, is protective of the environment via a cap (membrane and fill material) over sediment in the upper canal; this isolates the dripolene-related constituents from benthic organisms. A vertical barrier prevents movement of contaminated sediment and cap material downstream of the remedy. The lower canal supports a diverse benthic community and requires no remediation. Human health is protected by institutional and site controls.

5.3 Attainment of Media Cleanup Standards

This alternative complies with the non-numerical media cleanup goals by isolating sediments with elevated PAH concentrations that may adversely impact ecological receptors in the upper canal with a protective cap. Media goals will be met at the completion of corrective action construction.

The lower canal meets benthic health conditions by demonstration in the *Draft Benthic Study Report* (CH2M HILL 2014a).

5.4 Control of Source Releases

Alternative 2 controls releases of PAH constituents and prevents benthic contact with impacted sediment in the upper canal by providing a cap that contains and isolates the constituents with a protective physical barrier. No barrier is required in the lower canal.

5.5 Waste Management

Waste from construction activities such as dripolene coated materials, PPE, and decontamination fluids will be disposed of offsite by a licensed hazardous waste contractor. Implementation will comply with applicable permits.

5.6 Other Factors

Alternative 2 complies with other criteria as described in the following sections.

5.6.1 Long-Term Reliability and Effectiveness

The membrane and fill cap provide positive isolation between the impacted sediment and receptors in the upper canal. Fill and cap materials are stable and reliable containment for a performance life of 30 years or more. Sediment and cap material at the downstream end of the upper canal are horizontally contained by a vertical barrier to prevent movement downstream. Concentrations of PAHs exceeding media cleanup standards would remain immobilized below the cap. Rip rap or armor stone would protect cap fill from erosion.

Benthic organisms in the lower canal are thriving and show no signs of impacts from sediment constituents. Because of the depth of water, the deeper sediment (below benthic zone) constituents are not subject to wave and current erosion.

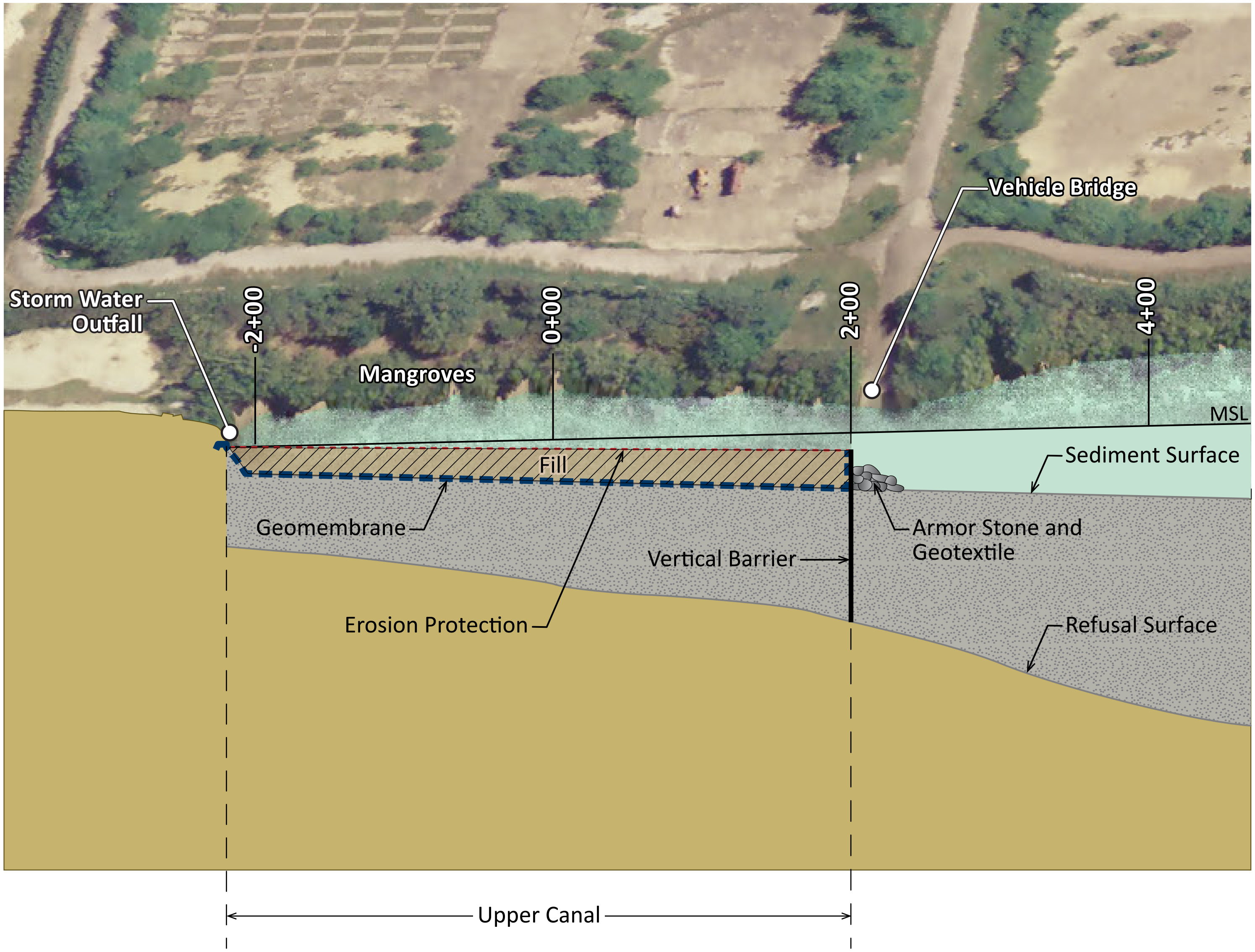
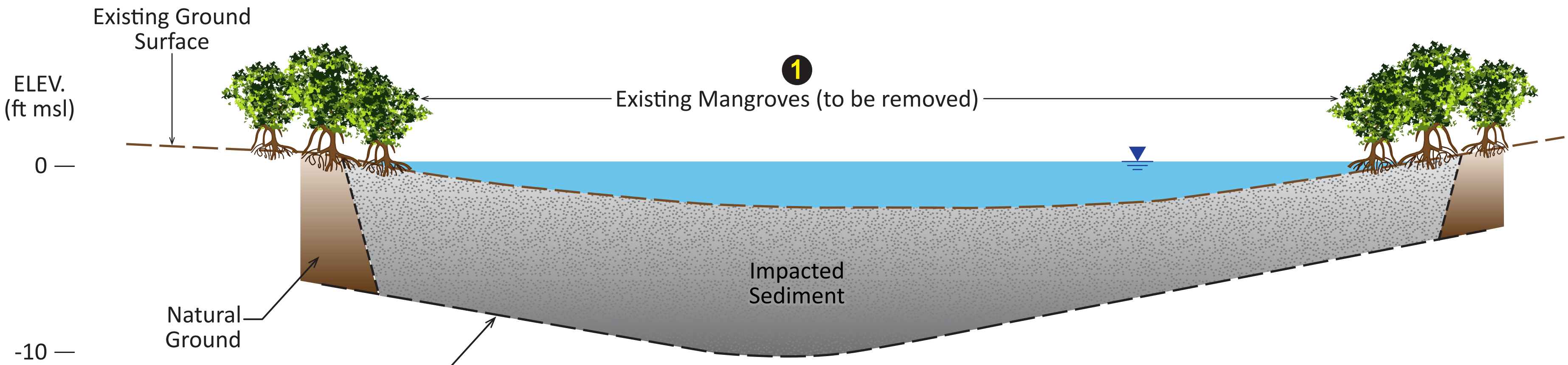


FIGURE 5-1
Profile: Recommended Alternative 2
SWMU No. 5 CMS Report
PTPLLC, Peñuelas, Puerto Rico



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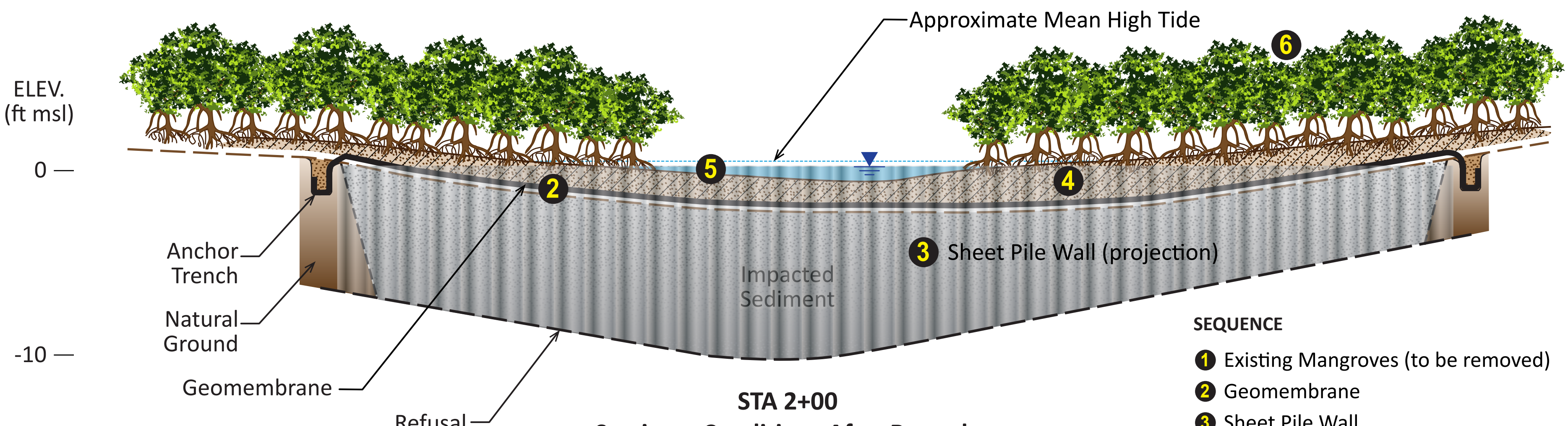
Section – Conditions Before Remedy



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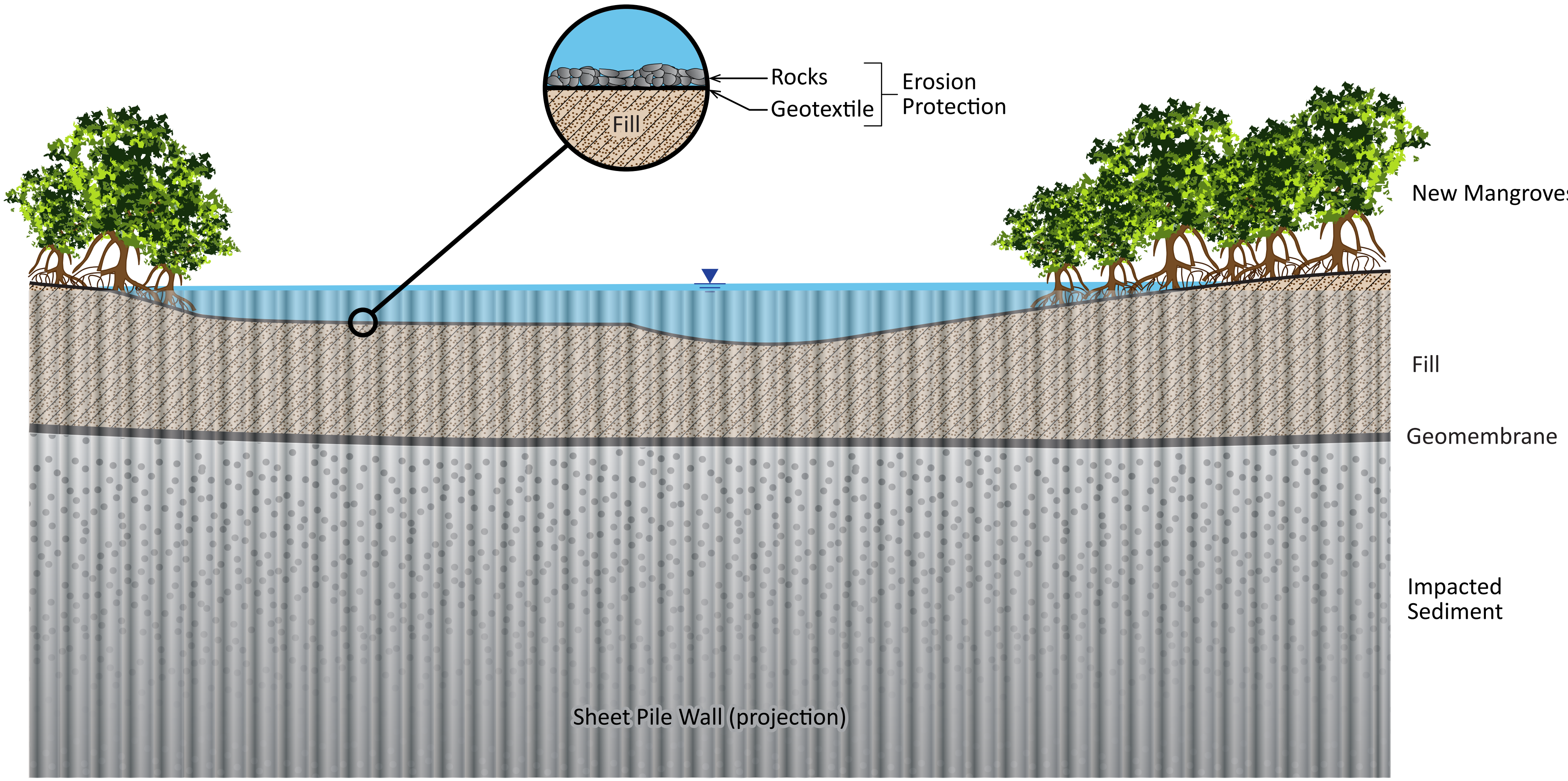
Section – Conditions After Remedy

SEQUENCE

1. Existing Mangroves (to be removed)
2. Geomembrane
3. Sheet Pile Wall
4. Topsoil and Caliche Fill (uncompacted)
5. Erosion Protection
6. New Mangroves

FIGURE 5-2
Sections: Recommended Alternative 2
SWMU No. 5 CMS Report
PTPLLC, Peñuelas, Puerto Rico



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Centerline Detail

FIGURE 5-3
Section Detail: Recommended Alternative 2
SWMU No. 5 CMS Report
PTPLLC, Peñuelas, Puerto Rico

CH2MHILL.

Given that significant impacts to benthic organisms do not currently exist in the lower canal despite numerous tropical storms and hurricanes that have hit the PTPLLC site over the life of the canal, additional storm events are not expected to significantly alter the conditions in the lower canal that may lead to significant impacts to the benthic community.

Administrative restrictions are expected to be effective in minimizing residual risk by preventing disturbance, erosion, and worker exposure to capped sediments in the upper canal and subsurface sediments in the lower canal during future industrial use.

5.6.2 Reduction of Toxicity, Mobility, or Volume of Wastes

Sediments are not treated, but mobility of PAH constituents is significantly reduced in the upper canal. Mobility is not an issue for sediment contaminants in the lower canal due to proposed administrative restrictions.

5.6.3 Short-Term Effectiveness

The area around the PTPLLC is industrial with no nearby residents. Risks to community during construction include material truck deliveries. These risks would be minimized through implementation of a construction health and safety plan. Employing appropriate health and safety procedures and protective equipment will minimize risks to workers from exposure to constituents.

Migration of disturbed sediment during construction would be controlled with BMPs such as turbidity controls.

5.6.4 Implementability

Clean Water Act and dredge and fill permits may be required to be filed and approved prior to placing cap and sheet pile wall. Application preparation and agency approval can take a year or more. Corrective action construction would likely take 4 to 6 months to implement. The capping technology and deployment equipment require specialized worker skills and equipment. Sheet pile technology and deployment equipment are proven and readily available in Puerto Rico. Filling was tested in the treatability study.

5.6.5 Cost

The total present worth cost of Alternative 2 is estimated to be $2,337,000, within a range of $1,635,900 to $3,505,500 in 2014 dollars.

This estimate is not intended to be of an accuracy equivalent to an offer for construction and/or project execution. Rather, these order of magnitude cost estimates are assumed to represent the actual installed cost within the range of - 30 percent to + 50 percent of the costs indicated. The cost estimate has been prepared for guidance in project evaluation and implementation from the information available at the time of the estimate. The final costs of the project will depend on the final design and actual labor and material costs, and competitive variability factors. Project feasibility and funding needs must be carefully reviewed prior to making specific decisions to help ensure proper project evaluation and adequate funding.

5.6.6 Ecological and Environmental Considerations

The mitigation of potential adverse impacts during the implementation of this remedy are identified and addressed in this section.

Habitat

In the short term, the aquatic habitat in the upper canal will be disturbed by removal of shoreline mangroves, the covering of the canal bottom and slopes with a geomembrane cap and fill, and incidental construction activities. After implementation, the upper canal area will consist of a drainage swale from the north end of the canal south to the vehicle bridge, surrounded by mostly wetland habitat (see sections in Figure 5-2). The fill used to construct this containment remedy will be evaluated for suitability to support wetland plant and benthic invertebrates. In some locations such as the north end of the canal and toward the side banks where existing elevations are too high, the cap and fill may elevate the finished grade to above a tidally influenced level which would inhibit development of wetland habitat, effectively preventing exposure of benthic organisms to underlying media and eliminating any subaqueous substrate for a benthic community to develop in the future. This upland area will be limited to the extent practicable to the margins of the construction area so that wetland habitat is maximized. The southern end of the swale will be at a lower elevation and tidally influenced; therefore, a new benthic community will develop on the fill substrate and roots of mangroves that become established in this area. The disturbed areas will be planted with suitable mangrove species to restore the area to a combination of aquatic and wetland habitats, with some minor new upland habitat. The planted vegetation will be monitored and managed until established. After substantial establishment, it will be allowed to mature naturally.

Mangroves

The capping (geomembrane and fill) work will require access to the upper canal for heavy equipment and anchor trenches for the geomembrane. This construction activity will involve removal of approximately 0.5 acre of vegetation from the upper canal and shoreline. Replanting of the mangroves in this disturbed area plus a portion of the capped area of the canal will be conducted to restore vegetative cover. The restored area is estimated to be approximately 0.8 acre. As advised by the U.S. Army Corps of Engineers (USACE) and the U.S. Fish and Wildlife Service (USFWS) in an internal memo (CH2M HILL 2014b) (Appendix E), changes in elevation and water depths prescribed by this remedy may dictate specific types of mangroves that are different than the mostly red mangroves that will be removed. Such types include black, white, and button mangroves. The specific types and planting locations will be coordinated with regulatory agency representatives during remedy design and permitting activities. Further mangrove mitigation efforts (if required) during design, permitting, and construction will be coordinated with representatives of the USACE, Puerto Rico Department of Environment and Natural Resources (DENR), USFWS, USEPA, and University of Puerto Rico, as appropriate.

Erosion

Temporary and permanent erosion control will be applied and maintained in the construction areas to control stormwater. Temporary erosion controls will consist of BMPs such as silt fencing, temporary ditches, hay bales, turbidity barriers, and others as well as construction stormwater permit compliance. Permanent erosion controls will be placed at the north and south ends of the swale as required, and consist of armor stone on geotextile to protect against long-term major storm flow damage.

Turbidity

Prior to any intrusive construction activity in or adjacent to the upper canal, turbidity barriers (floating silt curtains) will be installed and maintained downstream to contain suspended sediment. The curtains will consist of a solid plastic membrane with flotation tubes along the top and a chain ballast along the bottom to anchor the curtain to the bottom of the canal. The depth of the membrane (top to bottom) will be the same or greater than the maximum depth of the water column at the deployment location, and will accommodate elevation changes caused by tidal fluctuations. The curtains will be deployed from bank to bank to provide positive control of suspended solids. At least two curtains are being considered, one at the vehicle bridge, and one just downstream between the vehicle bridge and the dock. Additional curtain(s) will be available onsite to install in the event that turbidity migrates beyond the upper curtains. Surface water quality (visual cloudiness, turbidity in nephelometric turbidy units, total suspended solids [TSS]) will be monitored frequently before, during, and after construction activity in the upper canal in accordance with a detailed, approved water quality monitoring and management plan. The turbidity curtains will be left in place after final completion of the construction until turbidity and TSS have returned to background levels.

Manatees

Based on the provisions of Marine Mammal Protection Act, the Endangered Species Act, DENR requirements, and guidance from the USFWS, protection of manatees will be necessary during all elements of work occurring within the CWC. Manatees are known to occur at the mouth of the canal and have occasionally been observed farther up the canal from the mouth. Observers will watch out for manatees during canal work activities such as deployment of turbidity barriers. A form will be used to record observations.

Avoidance of manatees will be crucial to prevent collision or injury to manatees. This includes no-wake power boat use in areas where the vessel draft provides less than 4 feet of vertical clearance of the canal bottom; maintaining spotters for manatee presence during power boat operation; and shutdown of equipment/engines if a manatee approaches within 50 feet of the vessel.

SECTION 6

Public Involvement Plan

After completion of the CMS and remedy selection by the agency, the agency may request public comment on the Administrative Record and the identified corrective measure.

If the public is interested, a public meeting may be held. After consideration of public comment, changes to the CMS remedy may be required.

After consideration of the public's comments on the identified corrective measure, the agency may develop a Final Decision and Response to Comments to document the selected corrective measure, the agency's justification for such selection, and the response to the public's comments. Additional public involvement activities may be necessary, based on facility specific circumstances.

SECTION 7
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Appendixes

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